

The Archaeology of Local Human Response
to an Environmental Transformation

by

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ABSTRACT

This research addresses human adaptive decisions made at the Pleistocene-Holocene transition – the transition from the Last Glacial Maximum (LGM) to the climate regime in which humankind now lives – in the Mediterranean region of southeast Spain. Although on a geological time scale the Pleistocene-Holocene transition is the latest in a series of widespread environmental transformations due to glacial-interglacial cycles, it is the only one for which we have a record of the response by modern humans.

Mediterranean Spain lay outside the *refugium* areas of late Pleistocene Europe, in which advancing ice sheets limited the land available for subsistence and caused relative demographic packing of hunter-gatherers. Therefore, the archaeological records of Mediterranean Spain contain more generally applicable states of the Pleistocene-Holocene transition, making it a natural laboratory for research on human adaptation to an environmental transformation.

Foragers in Mediterranean Spain appear to have primarily adapted to macroclimatic change by extending their social networks to access new subsistence resources and by changing the mix of traditional relationships.

Comparing faunal records from two cave sites near the Mediterranean coast with Geographic Information System (GIS) reconstructions of the coastal littoral plain from the LGM to the Holocene indicates the loss of the large ungulate species (mainly *Bos primigenius* and *Equus*) at one site coincided with the associated littoral disappearing due to sea level rise in the late Upper

Paleolithic. Farther north, where portions of the associated littoral remained due to a larger initial mass and a more favorable topography, the species represented in the faunal record were constant through time.

Social boundary defense definitions of territory require arranging social relationships in order to access even this lightly populated new hunting area on the interior plain. That the values of the least-cost-paths fit the parameters of two models equating varying degrees of social alliance with direct travel distances also helps support the hypothesis that foragers in Mediterranean Spain adapted to the consequences of macroclimatic change by extending their social networks to gain access to new subsistence resources

Keeping these relationships stable and reliable was a mitigating factor in the mobility patterns of foragers during this period from direct travel to more distant down-the-line exchange. Information about changing conditions and new circumstances flowed along these same networks of social relationships.

The consequences of climate-induced environmental changes are already a concern in the world, and human decisions in regard to future conditions are built upon past precedents. As the response to environmental risk centers on increasing the resilience of vulnerable smallholders, archaeology has an opportunity to apply its long-term perspective in the search for answers.

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CHAPTER 1

INTRODUCTION

Climate change in mid-latitude Europe from the Last Glacial Maximum, circa 18,000 bp, to the Holocene at 11,700 bp (IUGS 2008a) caused an environmental transformation, which in turn prompted changes in human adaptation. These adaptative shifts were dramatic in Southwest France and in much of Western Europe but less so on the Iberian Peninsula south of the Cordillera Cantábrica. Throughout Europe, channels cut by alliance and mating networks changed in response to shifts in subsistence, demography, raw material acquisition patterns, mobility, and other factors (Gamble 1999; Schwendler 2012, 2004).

This period of climate change, known as the Pleistocene-Holocene transition, is the period of demarcation between climate-driven environments we know only from reconstructions (e.g. Carrión 2003, 2002, 2001a; Carrión et al. 2001, 1999, 1998, 1997, 1995) to the natural environments in which humankind now lives. Although the Pleistocene-Holocene transition is only the latest in a series of earth's glacial and inter-glacial cycles, it is the only one for which we have a record of the human response.

With the exception of relatively isolated montane glaciation in the Sierra Nevada, the Mediterranean region of Spain (Figure 1) was not directly affected by glacial advances and retreats that played a decisive role in forming the archaeological and paleoecological record in most of continental Europe. Instead, more subtle changes in resource distributions occurred as marine transgression

inundated much of the coastal plain, prompting late Upper Paleolithic hunter-gatherers to alter their subsistence practices, settlement patterns, social relationships, and alliance networks.

This study tests a specific hypothesis about the nature of human adaptation to the climate change, and ensuing environmental transformation, of the Pleistocene-Holocene transition in Mediterranean Spain.

Research Hypothesis

H₀: Environmental changes were relatively subtle compared to those in continental Europe, there were no significant changes in subsistence resources, demography, mating networks, raw material distributions, and forager mobility.

H₁: Foragers in the Mediterranean region of Southeastern Spain adapted to the consequences of macroclimatic change by extending their social networks to gain access to new subsistence resources and by recombining traditional relationships to shifting circumstances.

The null hypothesis is that compared to the retreating ice sheets, recolonization of newly revealed territories, and the dispersal of formerly concentrated reindeer herds in the *refugium* (Fischer 1996, 1991; Flagstad and Røed 2003) the Pleistocene-Holocene transition required little change in human adaptive responses. In strictly material terms, the early Post Glacial so much resembles the Late Glacial Magdalenian in Mediterranean Spain that is referred to

as the Epimagdalenian in peer-reviewed journals (Villaverde Bonilla 2012).

The hypothesis tested here originates in Elizabeth Cashdan's definition of social boundary defense (Cashdan 1983). Physical territories, like hunting territories through the Pleistocene-Holocene transition, were as areas to which hunter-gatherer social groups controlled access controlled by either in a tangible sense ("perimeter defense") or by controlling access to membership in the social group having rights to the resources in that area ("social boundary defense").

The main prey species did not change across the transition. As Jochim has noted "Late Palaeolithic hunters would not have faced a new and unknown suite of resources; they were already familiar with all of the major prey. What *was* new was the gradually changing habitat in which these prey were found, the slowly differing relative proportions of each ... In terms of optimal foraging theory, all of (the) large herbivores had already been in the optimal diet" (Jochim 1998: 194). Experienced hunter-gatherers looking for the same resources in the same territory were bound to come into contact based on the level of knowledge about animal behavior necessary to survive. This placed a premium not on new technologies, as evidenced by the Magdalenian to Epimagdalenian relative material continuum, but on new information about prey territories and new access to those territories.

The permission or social membership necessary to be in a hunting territory often comes with information about the territory, which in itself is an invaluable commodity. Permission, membership, and information travel along the same links of social relationships.

Humankind has always lived in an information age. The artifacts that are traditionally at archaeology's center of attention (Spaulding 1960: 437; Binford 1964: 429) are the material remains of decision-making based on available information and guided by precedents from earlier decisions. These culturally organized technologies shaped an important part of the means by which human groups adapted to local conditions (Binford 1989: 21). This should not be thought of as being an objective set of conditions rooted in an omniscient knowledge of possible variables. Late Glacial human perceptions of the conditions that initiated an adaptive response are founded on a specific point in time from which the available information had been gathered and prior to which the repertoire of past precedents had been set (Childe 1949, 1956).

“The environment to which a society actually adjusts itself is not the material environment that natural science can reconstruct and observe as an external object, but the society's collective representation of that environment – that is, part of its culture. Thereupon the attempt to observe even this environment confronts us at once with an acute case of the interaction and the instruments of measurement and observation. Using the instruments of nineteenth century culture to observe a culture of the nineteenth century B.C. is surely liable to alter the object and indeed to introduce distortions that must not be ignored.” (Childe 1949: 23)

The Pleistocene-Holocene transition can be thought of as a period when the correlation between survival and making good decisions was direct and more immediate. If a disconnect developed between human awareness of a situation and its natural reality, then the decision-makers perished. Information and precedent were key elements of prehistoric adaptation.

The hypothesis tested in this project is that Magdalenian hunter-gatherers in Mediterranean Spain extended their social relationships during the Pleistocene-Holocene transition, which granted them access to additional resources and helped them to mitigate the long-term effects an environmental transformation. This research addresses adaptive decisions made at the Pleistocene-Holocene transition, when much of the information available was literally unprecedented, in the Mediterranean region of southeast Spain (Figure 1), where a climate-driven environmental transformation affected the physical geography of subsistence.

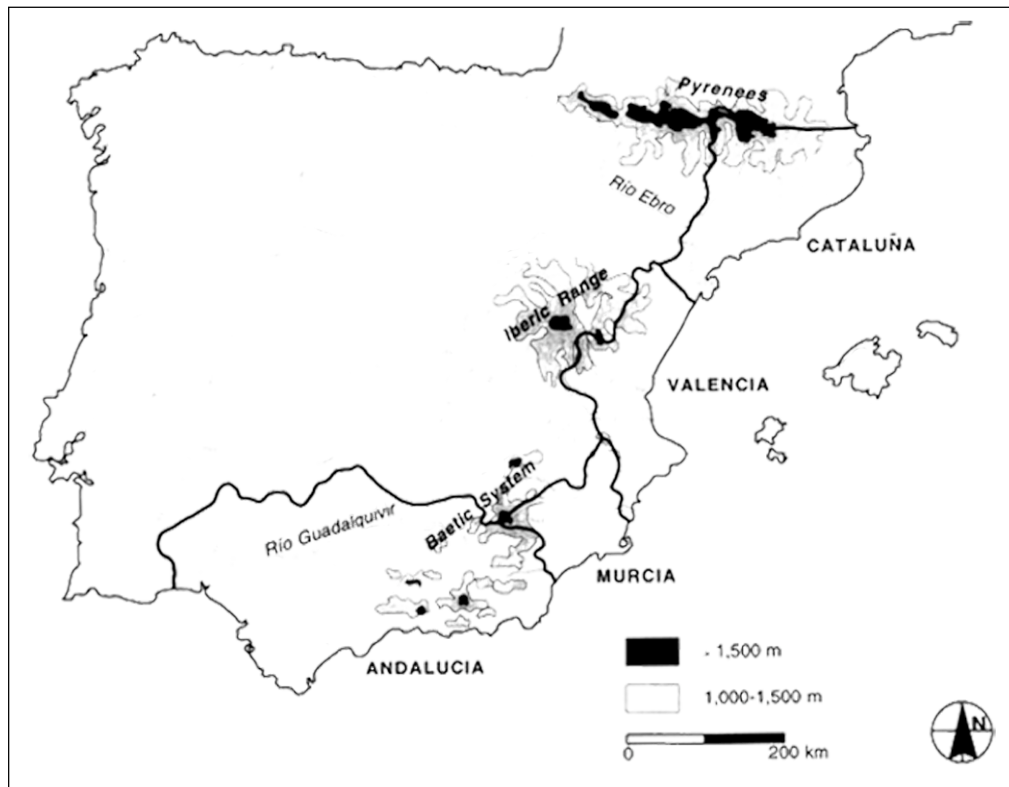


Figure 1. Regions of Mediterranean Spain.
After Villaverde et al. 1998: 124.

Technology has an observable presence in the archaeological record. Indications of Upper Paleolithic social relationships are more ephemeral in the archaeological record and more difficult to recognize when they do occur. But human adaptation is ultimately a social dynamic and a function of information communicated both within a group and between groups. While it is archaeological practice to trace the evolution of technology through artifact morphology and to make informed evaluations about patterns and outcomes, the terminal Pleistocene record for social dynamics, information networks, and exchange routes remains largely inferential. Prehistoric art in its parietal, mobile, and petroglyph manifestations could become a possible venue for understanding the social record. Art is arguably the only social manifestation of Upper Paleolithic culture created specifically as a social manifestation of culture. Our current knowledge of prehistoric art does not begin to approach the necessary depth, anymore than knowledge of Michelangelo's parietal painting in the Sistine Chapel explains decision-making based on the Catholic liturgy. However, when carefully placed in the context of other evidence, Upper Paleolithic art can be used to guide and shape archaeological inferences (Barton et al. 1994).

Argument by Analogy

Individuals and societies still cannot communicate directly with the environment. In the record of human adaptation to environmental transformation, this remains one of the constants in the midst of sweeping technological and demographic changes between the Pleistocene-Holocene transition and today. We still must communicate with each other about the environment (Luhmann 1989a,

1989b; van der Leeuw and Aschan-Leygonie 2000). Inferring past societal communication about the environment requires arguments by analogy, mapping what is observed onto analogous systems that are not observed and may be unobservable (Kosso 1999: 488). These carry the “standard strengths, risks, and limitations of arguments by analogy” (Kosso 1999: 488), including being evaluated based on similarities between the circumstances in observed and projected cases. However, Wylie has noted that despite our reasonable unease with arguments by analogy, “analogical inference is generally the basis for ascribing evidential significance to archaeology data” (Wylie 1992: 26-27).

Rules exist in the philosophy of science that govern the use and acceptance of arguments based on analogy:

“... analogical inference is subject to two sets of evidential constraints that can significantly limit the range of evidentially viable options: those determining what can be claimed about the analog based on knowledge of source contexts and those deriving from the archaeological record that determine its applicability to a specific subject context.” (Wylie 1992: 27)

Analogical argument has an obligation to demonstrate evidence of extensive similarity, what Wylie (1992: 27) calls “the completeness of mapping,” between the source of the analogy the subject context in which it is applied. There must be a reliable correlation between clusters of attributes in the source context that suggests the linkage inferred between archaeological material and its proposed significance is not entirely arbitrary (Wylie 1992: 27).

The security of archaeological evidence depends on the independence of the linking principles used to establish diverse lines of evidence bearing on the

claims presented (Wylie 1992: 28).

“If diverse evidential strands all converge on a given hypothesis – if you can use different means to triangulate on the same postulated set of conditions or events – then you may be able to provide it decisive, if never irreversible, support simply because it is so implausible that the convergence should be the result of compensatory error in all the inferences establishing its evidential support ...” (Wylie 1992: 28)

Convergence is independent of the hypothesis being tested. Convergence cannot be counted on or arranged. The quality of its independence is created when multiple lines of evidence and reasoning all lead to a single concept – and that is what gives convergence its decisive strength. Even if each line of evidence relevant to an inference about the past apparently displays a strong level of collateral support, when considered separately, undetected errors or weaknesses are made clear when a particular line of evidence consistently contradicts the others. Dissonance among the lines of interpretation – failure to converge on an internally coherent account – makes it evident that an error or errors is obstructing the flow between assumptions and linking principles (Wylie 1992: 28). Persistent dissonance is a sufficient cause to cast doubt upon “any interpretive constitution of the data as evidence” (Wylie 1992: 29). Convergence, in Wylie’s view, is actually reinforced by the feature of the archaeological record that necessitates arguments by analogy. The reality of archaeology that led Clarke to call it “the discipline with the theory and practice for the recovery of unobservable ... behaviour patterns from indirect traces in bad samples” (Clarke 1973: 17), is also one of its greatest assets:

“It is, paradoxically, the fragmentary nature of the archaeological record that is its strength in setting up evidential constraints ... even in establishing the limits of inquiry.” (Wylie 1992: 29)

Conceptual Frameworks

The intent is to develop a conceptual framework from analogous examples. Using the solar system as an analogy, the Danish physicist Niels Bohr suggested his atomic model of a compact central nucleus surrounded by orbital electrons. Although Bohr’s atomic model is now considered rather naïve and has been replaced by the more sophisticated theories of quantum mechanics, Bohr’s model was in fact the conceptual framework used to develop these more sophisticated theories. It is a pattern of theoretical descent with modification, which we are quite familiar with in archaeology. Bohr’s conceptual framework earned a 1922 Nobel Prize in Physics (Nobel Foundation 2007).

As the solar system is not a snapshot of atomic structure – the climate change of the Pleistocene-Holocene transition is not a snapshot of any future climate change. Research suggests that we can expect novel climates to develop and some known climates to disappear within the 21st century. While the Pleistocene-Holocene transition does not isomorphically map-on, point by point, to any future climate change, I suggest the process of human adaptation to that environmental transformation is a viable conceptual framework. We became us, anatomically modern humans, in the Pleistocene – a time we know only from inference and reconstructions. But we created successful new adaptations as Pleistocene climate disappeared, and the novel Holocene climate developed.

Environmental Transformation

Climate change and the environmental transformation that follows carries the risk that resulting ecological states will have no current analog (they will be unprecedented) and that some extant states will disappear (leaving invalid precedents in their wake). The Pleistocene-Holocene transition is the most recent example of a climate transformation and the only one for which we have a complete record of the human response. Researchers looking toward the end of the 21st century expect similar climatic restructuring that will “promote formation of novel species associations and other ecological surprises” (Williams et al. 2007: 5738). We know the transition from late Pleistocene to early Holocene included the redistribution of prey species and coastal littorals becoming undersea coastal shelves (e.g.; Milliken 1998; Schmich and McClure 2009). According to information currently available, the Pleistocene-Holocene transition remodeled the world in ways strikingly similar to effects the United Nations Framework Convention on Climate Change included in the Kyoto Protocol (UNFCCC 1999, 1998): widespread glacial retreats, sea level changes of more than 100 meters, shifts in weather and rainfall patterns, and altered floral and faunal ecologies (Aura *et al.* 1998; Straus 1996a, 1996b). Although Mediterranean Spain experienced both redistributions and ecological surprises, south of the Pyrenees Mountain region it lay outside the immediate area of the glaciation, refugium, and recolonization cycle that skewed human demographics in most of late Pleistocene Europe. Therefore, its archaeological and paleoclimatic records may contain generally applicable states of the Pleistocene-Holocene transition, making

Mediterranean Spain a natural laboratory for research on local human adaptation to global climate change (papers in Schmich and McClure 2009, Schmich 2008).

Including the local dynamics of human adaptation to prehistoric climate change in a comprehensive research strategy on modern climate stress is a logical extension of the emphasis predictive climate models place on inputs of Pleistocene data (e.g., Adams et al. 1999; Carter et al. 2007; Clark et al. 2001; Gibelin and Deque et al. 2003; Greiner 2004; IPCC 2007b; Karl and Trenberth 2003; UNFCCC 2004).

The economic consequences of global environmental transformation are already a concern in the world, and human decision in regard to future conditions are still built upon past precedents. In 2006, economist Nicholas Stern, chair of the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and chair of the Centre for Climate Change Economics and Policy at Leeds University and London School of Economics, released a comprehensive review of the scientific evidence for global climate change expressed in economic terms (Stern 2006). Stern's report concluded:

“(C)limate change is global in its causes and consequences, and international collective action will be critical in driving an effective, efficient and equitable response on the scale required. This response will require deeper ... co-operation in many areas - most notably in ... promoting adaptation, particularly for developing countries.”

(Executive Summary: 1 Stern 2006)

Stern went on to call climate change “the greatest and widest-ranging market failure ever seen” the economic recovery from which will require “long time horizons” that “have the economics of risk and uncertainty at centre stage” (*Executive Summary: I* Stern 2006). While Stern contended this process would draw on “ideas and techniques from most of the important areas of economics, including many recent advances (Ibid.),” his 2006 review tracks much of Redding’s general explanation of subsistence change from hunting and gathering to food production (Redding 1988), which views total economic change as a costly last option. Alternatives that maintain a known set of social relationships by which people orient their presence in the world seem preferable – even if that means changing the actual place in the world where those social relationships are set. Redding proposes emigration is the first option when subsistence risk necessitates action. If the full range meanings that archaeologists have applied to terms like emigration and migration is considered (Clark 1994), then it becomes apparent that the key to Redding’s concept of emigration is keeping intact the social group by which people orient themselves to their place and their relationships in the world even as that social group changes its location in the geographical world. Seasonal residential mobility by the entire group or extended logistical forays by task groups are within the purview of Redding’s (1988) proposal for mitigating subsistence risk. Negotiating access to new territories (the implication of the term emigration) suggests that the social groups engaged in negotiation maintained their group integrity.

Residential Mobility

Systems of social boundary defense as defined by Cashdan (1983) may result from inequity, where the subsistence resources of one social group meet more than its immediate needs while another group risks subsistence shortages (Kelly 1995: 198). Risk mitigation, in the form of access to land with greater subsistence resources, is arranged as permission established through kinship (including marriage networks), friendships, or partnerships (Cashdan 1983).

Residential mobility is a common solution to local subsistence risk by allowing hunter-gatherers to map-on to unpredictable, or unprecedented, resource distributions (Binford 1980, Kelly 1983, Kuhn and Stiner 2001: 106). Such mobility is commonly observed in recent forager studies (Kuhn and Stiner 2001: 106), and its outcomes are observable in the archaeological record. As common a strategy as mobility may be, it comes with conditions and consequences:

“Uninhibited residential mobility is only feasible in a relatively empty environment, however. If many foraging groups have an interest in the same set of resources, access must be co-ordinated or selectively restricted in order to avoid conflict. Virtually all documented foraging groups thus possess norms of land tenure or preferential access to resources.” (Kuhn and Stiner 2001: 106)

The scale of the groups making these decisions on cooperative land tenure and participating in resource access decisions is an important consideration. Smaller groups have more immediate flexibility to create or rescind subsistence-based partnerships, but they have less resilience (Redman and Kinzig 2003) in the form of other options necessary to enter into such alliances and networks freely –

or to enforce the end of such alliances and networks. Holling's original definition of resilience as a "measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations ..." (Holling 1973:14) is applicable to the dynamics that shaped social relationships across the Pleistocene-Holocene transition in Mediterranean Spain. Larger groups may have less initial flexibility to respond to local conditions, but they may also have more to offer in negotiating relationships and to be better able to absorb the results of alliance and network agreements, as well as any conflict that could result. Group size in these cases is not solely a function of population. The territorial extent of a group also determines its options. Once a cooperative agreement is reached, the cooperating groups may be considered members of a single group when making future alliance decisions. Moreover, group membership on a standing, daily basis need not be a requisite to accrue the benefits and obligations of alliances and networks.

Kuhn and Stiner (2001: 114) note that the "kinds of socially-mediated options for managing resource risk associated with trading networks (for example) among recent hunter-gatherers seem to have been quite widespread during the LUP [Late Upper Paleolithic] and Epipaleolithic." MacDonald (1999) links non-local lithic raw material with socially mediated travel that included finding potential mates among dispersed groups of hunter-gatherers and, perhaps, the maintenance of marriage networks. However, non-local lithics can also be linked with Cashdan's (1983) social boundary definition to infer that a group or groups either had direct access to the territory in which the lithic source was

located or had social permission to access the territory in which the lithic source was located. MacDonald (1999) also notes that non-local lithic materials can be acquired indirectly through trade. Determining whether non-local lithics were acquired directly from a 'home' territory, through socially mediated access to a territory, or by trade, which also defines a social relationship, is difficult because each leaves similar imprints on the archaeological record (MacDonald 1999). Hunter-gatherers were more likely to curate non-local lithic material to minimize the risk of depletion. Therefore, the most common trace of non-local lithic material in any give assemblage is more likely to be evidence of curation (i.e.; pressure flakes from retouch and resharpening) than evidence of direct use.

Archaeologists in North America view Paleo-Indian communal hunts of *Bison antiquus* (and later prehistoric and proto-historic hunts of *Bison bison*) as opportunities for social aggregation (Bamforth 1991; Hofman 1994; Hill 2007: 285-288) to create and maintain alliances. The implied relationship between communal hunts large animals that gather in large herds and social aggregation of human groups is a two-way street. Taking advantage of large prey in large herds requires planning and preparation before the hunt, and a labor force sufficient to process the results of the hunt afterward (Frison 2004: 167-168, 225-227).

In Mediterranean Spain, socially cooperation was mediated by the system of natural corridors connecting the coastal littoral with the southeastern interior plain, the Meseta. Social cooperation was necessitated by the changing conditions of the Pleistocene-Holocene transition. Natural meeting points on the ecotonal edges of the region have the added advantage of being easily located and

described, socially communicated, by diverse social groups planning a communal hunt – meeting the preconditions determined by Hofman (1994) and Hill (2007: 286-287) from their work on communal bison hunts in North America during essentially the same time period of climatic and environmental development.

Current research in Mediterranean Spain suggests that Upper Paleolithic hunter-gatherers may have relied on intensive use of lower ranked resources (Jochim 1983), especially lagomorphs/leporids, between the Last Glacial Maximum and the Pleistocene-Holocene transition (Aura et al. 2002, Villaverde et al. 1998) to make up for subsistence shortfalls.

In writing about the end of the Upper Palaeolithic in Mediterranean Spain, Villaverde acknowledges that the “presence of rabbits is overwhelming in comparison to that of other taxonomic groups ... Studies conducted indicate that lagomorphs were consumed by humans” (Villaverde et al. 2012: 8). Haws notes that even though rabbit ranks low in the overall diet based on meat weight, “the undeniable fact is that their remains do not just dominate assemblages, they swamp them in many cases. People went to some effort to procure them on a large scale. Why?” (Haws 2003: 57). Haws’ question has been asked by other Iberian archaeologists as well and merits consideration (i.e., Aura Tortosa et al. 2002; Hockett and Haws 2002; Jones 2011).

European rabbits, in modern studies, live in warren systems of burrows in which they give birth and hide during instances of risk. As rabbit litters mature, the young rabbits disperse up to 1500 meters from their home warren and establish new warrens. There may be four to eight warrens within a square

kilometer. Rabbit warrens and rabbit behavior makes them relatively easy to find and to exploit in large numbers.

Frison's direct experience provides another level of understanding:

“Cottontails (note: North American rabbits) hide in brush or remain visible at or close to holes into which they can dive at any indication of danger. ... (A)t a very early age I was shown ... a green branch with a forked end could be inserted into the hole until it touched the rabbit. A few twists anchored it firmly enough into the rabbit's fur so that the animal could be pulled to the surface.” (Frison 2004: 191)

The possibility exists that as archaeologists in the 21st century we are overthinking rabbit hunting and exploitation in the Upper Paleolithic. As small prey, rabbit can be assumed to have been carried back to residential sites whole, without any field processing beyond the cursory (Arroyo 2009: 28). This assumption is included in Metcalfe and Barlow's model exploring the optimal trade-off between field processing and transport (Metcalfe and Barlow 1992). Its explicit reduction of small prey processing to a single point equivalent to the total caloric yield of the animal “carried whole to the camp” suggests an answer to the question of why and how rabbit swamped the counts of all other species in Mediterranean Spain faunal assemblages during the Pleistocene-Holocene transition. In writing about the end of the Upper Palaeolithic in Mediterranean Spain, Villaverde acknowledges that the “presence of rabbits is overwhelming in comparison to that of other taxonomic groups ... Studies conducted indicate that lagomorphs were consumed by humans” (Villaverde et al. 2012: 8).

In addition to Frison's experience above, historic accounts of rabbit

poaching in Europe and the British Isles also suggest rabbit were targeted specifically because they did not require special effort (see Osborne and Winstanley 2006; Manning 1994; Bailey 1988).

Hockett and Haws (2002: 293, Table VI – Table 1 below) summarize the Number of Identified Specimens Present (NISP) data presented for the Late Upper Paleolithic in Mediterranean Spain (Aura Tortosa and Pérez Ripoll 1995). They note that in the Late Magdalenian, rabbit accounted for 23,162 NISP for all faunal assemblages in Mediterranean Spain. As a comparison, *Equus* and *Bos*, for example, account for 86 NISP for all assemblages.

Table VI. Summary of NISP of Fauna From Late Upper Paleolithic and Mesolithic Sites in Mediterranean Spain (Adapted From Aura Tortosa and Pérez Ripoll, 1995)

	MSM ^a (Late Magdalenian)	EMM ^b (Epipaleolithic)	EGM ^c (Mesolithic)
Equus sp.+ Bos sp.	86	39	8
Cervus elaphus	1543 (6%)	2381 (16%)	379 (10%)
Capra pyrenaica	1227 (5%)	1430 (9%)	1057 (37%)
Rupicapra + Capreolus	11	39	18
Sus scrofa	1	70	45
Leporids	23,162 (87%)	11,005 (72%)	1327 (46%)
Carnivores	64	81	23
Birds	537	272	18

^aMagdalenian Superior Mediterráneo (13,000–11,000 B.P.).
^bEpipaleolítico Microlaminar Mediterráneo (11,000–9000 B.P.).
^cEpipaleolítico Geométrico Mediterráneo (9000–7500 B.P.).

Table 1. Summary of Number of Identified Specimens for Late Magdalenian sites in Mediterranean Spain. (Hockett and Haws 2002: 293, Table VI)

Breaking the data into manageable parts changes the inference and apparent emphasis. If a minimal band of 25 adults (Wobst 1974) stopped at a residential site with rabbit warrens in the vicinity for two weeks on their way

through the mountain corridors to the Meseta and two weeks again on their way back each year (an annual round) – and if each adult ate one rabbit a day while they were there – that minimal band alone would accumulate 23,100 rabbit carcasses in about 33 annual rounds. The variables can be parsed in any number of ways – all of which result in a large number of rabbit carcasses accumulating in not much time. Rabbit may have been a resource of convenience for residually mobile hunter-gatherers whose mental templates of their subsistence landscape included the relatively static location of rabbit warrens.

Intensification

If the proposition that intensification supplanted mobility relatively early in the Upper Paleolithic of Mediterranean Spain (Aura et al. 2002) holds true, then mobility may not be the intrinsic element of long-term, subsistence adaptation to climate change and newly extended social relationships may not have been required. In effect, the null hypothesis may be correct.

However, intensification may only be a short-term solution and may initiate a cycle of diminishing returns (Redman 1999, van der Leeuw 1998). For example, intensified reliance on lagomorphs could lead foragers to make decisions based on a convenient, secondary resource skewing daily and seasonal time-investments. If this further stressed the coherence of the subsistence system, then faunal assemblages showing lagomorph intensification may be evidence of short-term problem solving rather than a shift of sustainable strategies. Moreover, lagomorph intensification may be evidence of something entirely different. The apparent increase of rabbit in faunal assemblages could represent the

accumulation of a convenient resource exploited by hunter-gatherers traveling through east to west natural corridors on their way to access herds of large ungulates (*Bos* and *Equus*) on the Meseta.

Human Adaptation to Environmental Transformation

There is a teleological component to survival in human terms. Although Childe (1949) notes that human groups did not adapt to the environment as it is but adapted to their perception of the environment, and Luhmann (1989) argues that in lieu of the ability to communicate directly with the environment when formulating adaptive strategies humans are left to communicate with each other about their view(s) of the environment or to exchange their interpretations of information gathered about the environment, neither doubts the intentionality of human adaptation.

This research addresses adaptive decisions human groups of hunter-gatherers made at the transition from terminal Pleistocene climates we know only from reconstructions using proxy data (pollen, charcoal, coprolites, faunal assemblages, macro-botanicals, etc.) to the Holocene climate regime in which we now live. The focus is on the environmental transformation that results from global climate change rather than the climate change itself. During the Pleistocene-Holocene transition much of the information available throughout areas continental Europe inhabited by humankind was literally unprecedented. For example, recent work offshore on the Dogger Bank, on what is now a large sandbank in a shallow the North Sea about 100 kilometers from England's eastern coast, indicates that sea level changes resulting from massive pulses of glacial

meltwater could occur abruptly and within a human generation (Fitch et al. 2005). The possibility also exists for catastrophic to change the trajectory of environmental transformation. A tsunami triggered by the Storegga Slide off the west coast of Norway at about 8200 bp may have been the final event submerging the Dogger Bank (Bryn et al. 2005; Grauert et al 2001; Weninger et al. 2008) In the Mediterranean region of southeast Spain, environmental transformation affected the physical geography of subsistence as mean sea level rose and submerged a major portions of a coastal littoral habitat.

Although contemporary subsistence economies tend to be agricultural and pastoral, they are not as distanced from past hunter-gatherers as they may seem.

- The International Center for Tropical Agriculture notes that besides crops and livestock, livelihoods in subsistence households can incorporate fishing ... hunting and gathering (Streck 2012: 12).
- The Food and Agriculture Organization of the United Nations defines smallholder populations as all persons depending for their livelihood on agriculture, hunting, fishing or forestry (Dixon et al. 2001: 3).
- In a more far reaching conceptualization, smallholder and subsistence farmers and pastoralists are recognized to practice hunting/gathering of wild resources in addition to crop and livestock production to fulfill their energy, clothing, health, and cash income needs as well as direct food requirements (Morton 2007: 19680).
- The United Nations Intergovernmental Panel on Climate Change even more directly equates smallholders with hunting and gathering:

“Smallholders and Subsistence Farmers and Pastoralists ... often practice hunting-and-gathering of wild resources to fulfill energy, clothing and health needs, as well as for direct food requirements.”

(Easterling et al. 2007: 281)

Beyond these points, smallholder agriculture is subject to what has been called "the centrality of the social:" its grounding in social relations within households (particularly gender relations) and between households, profoundly affects the negotiation of production decisions, management of knowledge, and marketing (Morton 2007: 19680).

Moreover, if we use a simple definition of a successful subsistence adaptation as being “access to sufficient resources” – then changes in technology affect how access occurs and changes in demography alter what is sufficient – but the basic structure of the equation still holds across time.

Placing the long-term perspective of archaeology in the range of options for modern decision-making (van der Leeuw and Redman 2002; Tainter 2000, 1995) recognizes environmental transformation as a challenge that local subsistence economies previously confronted with success. Archaeology has an opportunity to apply its unique understanding in the search for responses to assist smallholders (Easterling et al. 2007: 281) in subsistence economies of developing countries, those who inhabit the vanguard of risk and vulnerability now associated with anthropogenically-accelerated climate change.

CHAPTER 2

LINES OF EVIDENCE

In 1967, Raymond Davis Jr. placed a vat containing 3,900,000 liters of dry cleaning fluid (tetrachloroethene) deep in a mine shaft and isolated the measurable presence of solar neutrinos for the first time (Davis 1968; Hudson 1994). In doing so Davis, who was primarily a chemist, called into question the inferences from observation made by astrophysicists. Davis never directly observed a neutrino. No one had. Solar neutrinos were understood to be ghostlike particles that existed in purely theoretical models of the solar interior first developed by Wolfgang Pauli in 1930. Produced by the nuclear reactions that create the sun's energy, neutrinos were believed to have no mass. According to prevailing theory in astrophysics, solar neutrinos flowed through each square inch of the earth at the rate of about 400 billion per second (Brookhaven National Laboratory 2004). When Davis counted only about one-third as many neutrinos in his experiment he began a cross-disciplinary controversy with astrophysics.

Davis' work relied on a chain of analogical inferences, leading from one to the next. Chemists were unimpressed. They viewed the Davis experiment as an example of normal science (*sensu* Kuhn 1967/1970).

“The reactions of chemists to Davis' result has been that as far as they are concerned he is just doing standard chemistry – admittedly, on a slightly larger scale than is usual – but, nevertheless, standard chemistry.”

(Pinch 1980: 94, quoted in Hudson 1994: 83-84)

Davis helped to originate the chemistry he used to measure solar neutrinos. He had been doing similar, smaller scale experiments for a decade.

“It is precisely because Davis' work acceded to (then) current strictures on experimental procedure that (astrophysicists) found Davis' low neutrino count so alarming. It would not be true to say that (astrophysicists were) concerned because Davis had found the 'truth' with respect to how many solar neutrinos bombarded his detector. The truth in this matter was, and still is, a hotly debated issue. Rather, Davis' experimental work was compelling because, according to the standard set by the scientific community, he had not done anything wrong. Despite ... efforts to isolate potential sources of experimental error ... Davis' work passed the palm of experimental adequacy.” (Hudson 1994: 84)

When neutrinos collided with the chlorine in the Davis' dry cleaning fluid, they produced radioactive argon, which subsequently decayed. He recorded the decay with a Geiger counter. By examining Geiger clicks, Davis was able to ascertain the presence of solar neutrinos and correct for possible ambient sources of neutrinos (Hudson 1994).

The discrepancy between theoretical solar neutrinos from solar observations and measured numbers of neutrinos on earth would be resolved by an advancements in neutrino physics made possible by Davis' conceptual framework and astrophysics' response to his challenge. In 2002, Ray Davis earned part of the Nobel Prize in Physics for his experiment that found the number of solar neutrinos was about one-third of the number predicted by the original Standard Solar Model (Nobel Foundation 2002).

The philosopher of science Peter Kosso, who writes about archaeological

method and theory (e.g., Kosso 2006, 2001, 1996, 1993, 1992, 1991; Kosso and Kosso 1995), has suggested that the importance of the Davis case study to archaeological practice is its verification that a chain of logic can successfully challenge theoretical inferences based on observation (Kosso, personal communication, 1999).

Inferring social communication – the transfer of information and judging the value of new information – in anthropology, and archaeology by extension, has less philosophical distance to travel than Davis’ foray into astrophysics. Davis was a chemist who crossed disciplinary boundaries and challenged the established beliefs of physics. In anthropology social concepts already have been used to define physical territories. Cashdan (1983) uses them to define land-based territories as areas to which access is controlled by social groups either in a physical sense (“perimeter defense”) or by controlling access to membership in a social group having rights to the resources in an area (“social boundary defense”).

This study suggests social relationships, which do not preserve in the archaeological record, were extended during the environmental transformation of the Pleistocene-Holocene transition in order to access new hunting territories for large prey (specifically *Equus* sp. and *Bos primigenius*), for which archaeological sites have either not been found or not been recognized, made necessary when the herds moved east to the edge of the Meseta due to loss of a habitat most of which is now inaccessible under the Mediterranean Sea. It relies on the chain of logic precedent and tenets similar to Davis’ neutrino study.

Lines of Evidence: Coastal Littoral Reconstruction

Three lines of evidence suggest that *Bos primigenius* and *Equus* sp. were hunted on the littoral exposed by the Last Glacial Maximum (LGM) and remained optimal prey after the littoral was largely inundated by rising sea level. *Bos* and *Equus* would have been Mediterranean Spain's largest herbivores in the Late Upper Paleolithic and primary sources of fat, a higher value nutrition element for hunter-gatherers than general meat calories (Speth and Spielmann 1983).

Fat was the most concentrated type of dietary energy available on the Late Upper Paleolithic landscape – fattier foods have higher energy yields for each unit of weight than other foods (Jochim 1981: 82). Moreover, fat content correlates with protein content in most foods. Meat with a fat content of 5% or more per edible portion have 10% or more of raw protein (Jochim 1981: 82). But there is a caveat in that the fat/protein relationship is not the same as the protein/fat relationship. Many high protein foods have a low fat content (Jochim 1981: 82).

Fat content would have been a factor in optimal foraging decisions on which territories to hunt based on available information. Fat content of accessible prey also would have a role in negotiating relationships and alliances.

“The problem of obtaining enough fat is crucially important and may be a mechanism for exploring group mobility in the past. (B)oth the quantity and location of animal body fat changes throughout the year, according to season. This also varies between species, and in a fat-focused strategy this would impact on patterns of carcass transport and on butchering and processing strategies. “ (Pryor 2008: 167)

Species group	NISP ¹ (%)	MNI ¹ (%)	MW ² (%)
Saiga antelope/reindeer	89.7	77.4	17.3
Large bovids	3.8	10.5	64.5
Horse	6.4	12.1	18.2

Table 2. Magdalenian faunal assemblage
Saint-Germain-la-Rivière, Southwest France

Number of Identified Specimens (NISP)
Minimum Number of Individuals (MNI)
Meat Weight (MW) ratios .

¹ NISP ratio and MNI ratio calculated from Costamagno (1999) relative to the the total of saiga antelope, reindeer, large bovids, and horse.

² Meat weight (MW) ratio calculated relative to the total of saiga antelope, reindeer, large bovids, and horse.
Mean weight values from Speiss 1979: 214, Table 6.13

(Drucker and Henry-Gambier 2005: 31, Table 4)

However, optimal foraging decisions are difficult to assess from the material remains in the archaeological record. Late Upper Paleolithic faunal assemblages may not be an entirely accurate reflection of the landscape potential available to hunter-gatherers. Table 2 shows the ratios of the four main species (saiga antelope and reindeer are combined) from the Magdalenian faunal assemblage at Saint-Germain-la-Rivière in Southwest France (Drucker and Henry-Gambier 2005: 31, Table 4) displayed by Number of Identified Specimens (NISP), Minimum Number of Individuals (MNI), and estimated Meat Weight (MW). Relying on the basic units of faunal analysis measurement (NISP and

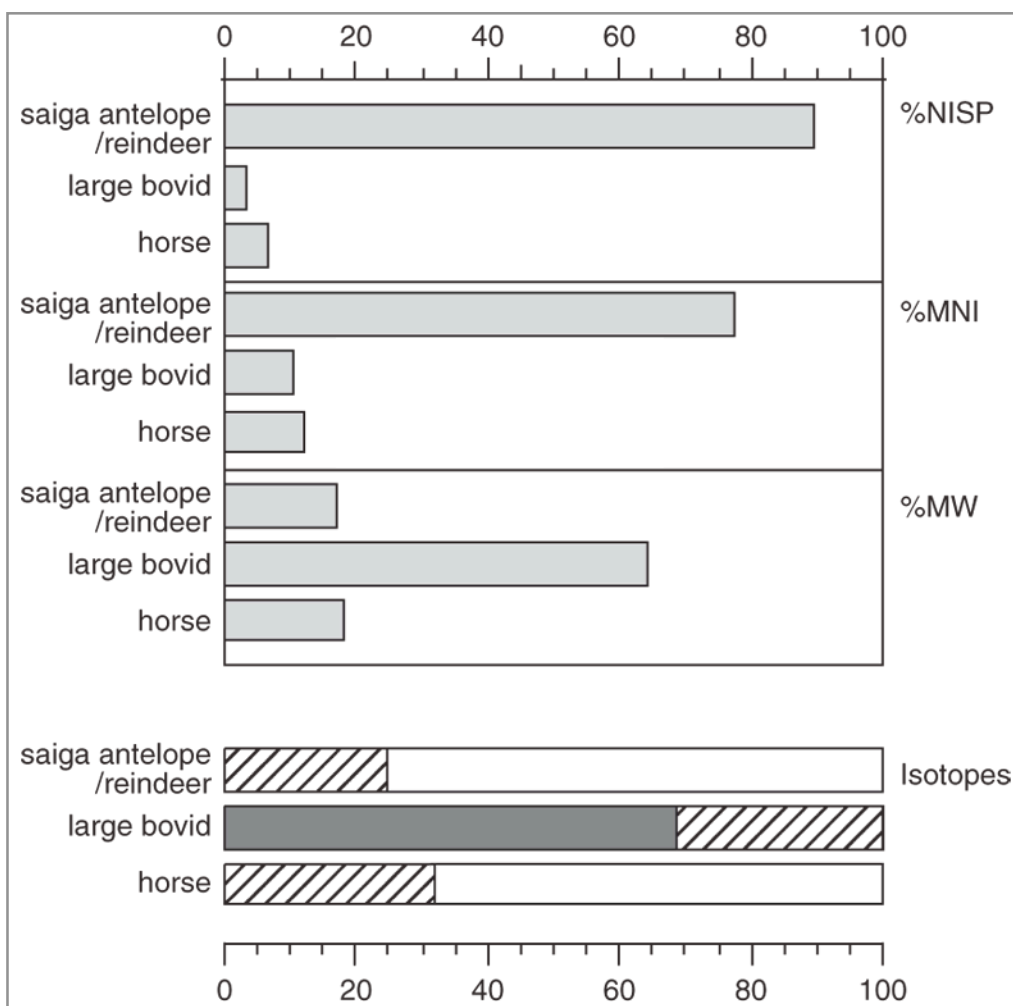


Figure 2. Discrepancy between ratios of species in Magdalenian faunal assemblage at Saint-Germain-la-Rivière, Southwest France and ratio of species in human diet from isotopic analysis and NISP.

Number of Identified Specimens (NISP)

Minimum Number of Individuals (MNI)

Meat Weight (MW) ratios

(Drucker and Henry-Gambier 2005: 31, Figure 7)

MNI), saiga antelope/reindeer clearly dominate. Using estimated meat weight (MW) suggests optimal foraging decisions were based on hunting large bovids (64.5% of total), with saiga antelope/reindeer third in importance (17.3%).

Saint-Germain-la-Rivière also afforded a unique opportunity for isotopic analysis of bone collagen from a Late Upper Paleolithic female. The calculated range of prey consumed (Figure 2) shows that human consumption correlates much more strongly with estimated meat weight than the NISP and MNI ratios from the faunal assemblage (Drucker and Henry-Gambier 2005: 31, Figure 7).

“Application of a linear mixing model to the woman’s isotopic signature indicates that (1) no significant marine-derived protein contributed to her average diet; (2) saiga antelope, which dominates the faunal remains at Saint-Germain-la-Rivière, was not the main source of terrestrial protein; and (3) her pattern of subsistence reflects a less opportunistic behavior than generally attributed to humans from this period.”

(Drucker and Henry-Gambier 2005: 19)

Some herbivores store large amounts of bone marrow fat relative to body size. For example, reindeer have more bone marrow fat than horses and bovids. This may account for reindeer being transported from kill site to residence as an intact carcass (along with size and weight), while post-cranial elements of horse and bovids are relatively rare in faunal assemblages (Pryor 2008: 168).

“In a rare glimpse of Upper Palaeolithic butchering practises viewed from the perspective of a kill site ... (analysis of) the fauna from the summer-time horse-hunting site of Stránská Skála IV [Czech Republic], dated to c.18,000 bp (uncal) ... suggested that although most of the post-cranial bones were abandoned at the kill site, almost all of the heads had been taken away. Interestingly, heads are one of the most stable and predictable

fat reserves in a carcass because the fats stored in the brain, tongue, nose and lips are among the last reserves to break down during starvation.“
(Pryor 2008: 168)

In the specific case of Mediterranean Spain during the Pleistocene-Holocene transition, reindeer were not an available option. The main species from regional faunal assemblages were *Cervus elaphus*, *Capra* sp., *Equus* sp., *Bos primigenius*, and *Leporidae*.

The winter fat content of adult male *Cervus* is listed in Spiess (1979: 214, Table 6.13) as 2%. Two studies of domesticated male red deer in New Zealand found the total carcass fat content was even less, 1.3% (Stevenson et al. 1992; Drew 1985). *Capra ibex* has an adult male winter fat content of 5% (Spiess 1979: 214, Table 6.13), but that is based on an estimated meat yield of only 22 kilograms. *Equus caballus* has an adult male winter fat content of 5% (Spiess 1979: 214, Table 6.13) based on an estimated meat yield of 192.5 kilograms, second only to *Bos primigenius* for meat yield in the region. Domesticated horse raised for meat in Korea upgrades the fat content slightly to 6% (Lee et al. 2007). Adult male large bovines (e.g., *Bos primigenius*) have a winter fat content of 5% based on an estimated meat yield of 770 kilograms (Spiess 1979: 214, Table 6.13). Interestingly, Spiess (1979: 214, Table 6.13) lists *Lepus*/*Leporidae* as having a winter fat content of 0% based on an estimated meat yield of 2 kilograms. This runs counter-intuitively to the composition of most faunal assemblages in Mediterranean Spain (e.g., Table 1 above).

When sea level rose in the Mediterranean Sea as the Fennoscandian and Alpine ice sheets melted, the coastal littoral was inundated and hunting for herds with a preference for open plains, like *Bos* and *Equus*, in the region shifted to the southeastern edge of the Meseta, Spain's interior plateau. The change in hunting venue from adjacent coastal littoral in the east to more distant Meseta in the west necessitated an extended series of social relationships to gain access, as outlined in Cashdan's (1983) definition of territorial social boundary defense.

The first line of evidence is a reconstruction of Mediterranean Spain's coastal littoral, and its proposed value as a hunting territory during the LGM and for a relatively short period after the LGM. The reconstruction is based largely on work initiated at Gorham's Cave near Gibraltar (Finlayson et al. 2008a) and the Biological Preserve of Doñana National Park, also near Gibraltar (Finlayson et al. 2008b). The research was quantified to correlate fossil pollen and macrobotanical material from excavated and radiocarbon dated contexts with analogous landscapes that could be observed directly. These outcomes were verified and extended north to Cape Palos, near Cartagena in the Murcia province of Spain, based on a littoral plain exposed by a 110 meter drop in mean sea level (Carrión et al 2008). This project extends the reconstructed littoral plain from Cape Palos another 200 kilometers north to Capo de la Nao based on a more conservatively reckoned littoral plain exposed by a 100 meter drop in mean sea level at the LGM.



Figure 3. Distribution of pre-Magdalenian Sites on the Iberian Peninsula. After Schmidt et al. 2012: 3

Lines of Evidence: Natural Corridors

The second line of evidence is an analysis of estimated travel costs for a network of natural corridors (Aura et al. 1993) connecting the Mediterranean coastal littoral to the southeastern edge of the interior Meseta through a series of mountain valleys. Aura's early work viewed the geophysical structure of Mediterranean Spain, and reconstructions of coastline variations, as a diachronic path for tracing the distribution of archaeological deposits in the pre-Neolithic period stretching from 500,000 bp to 7000 bp. Aura proposed that the region's main natural corridor ran not east to west through the mountains but north to south along the mountains on the first shelf of the coast littoral exposed from about 18,000 bp (the LGM) to about 11,700 bp (the Holocene onset). He notes

that the overarching geographical fact of Mediterranean Spain is that the region is a north-south corridor attached to the front of mountainous terrain (Aura et al. 1993: 104-105), which is mirrored in the coastal distribution of pre-Holocene archaeological sites in Figure 3. The appearance of a tanged Parpalló point in a Solutrean level at Vale Boi, on the southwest coast of Portugal, extends Aura's north-south axis more than 500 kilometers past Murcia. The fact that the Vale Boi Parpalló point is made on local chert from a source 10 kilometers away fosters Aura's idea that there was communication along the north-south coastal littoral corridor rather than exchange of a specific point originating at Parpalló near Gandia, Spain.

However, even as Aura's initial work on natural corridors identifies the additional difficulties inherent to east-west communication along natural corridors through the mountains bordering the exposed coastal littoral, it recognizes that such communication did exist – expressed primarily through the use of ornamental objects like marine shell. Aura suggests a complementary use of coastal and interior (Meseta) environments made directly or indirectly through exchange relationships. Importantly, Aura (et al. 1993: 106) times these Meseta-littoral exchange relationships to the Pleistocene-Holocene transition. He calls the social relationships between coast and interior, lowlands and highlands, a reference point to be developed by further research (*“la relación costa-interior, tierras bajas-tierras altas sigue siendo un referente a desarrollar”* [Aura et al. 1993: 106]).

As work on the natural corridors evolved, Iberian researchers noted a

significant degree of parallelism among the regions as seemingly disparate and geographically removed from each other as the Portuguese Estremadura, Cantabrian northern Spain and the Mediterranean of southeast Spain (Aura et al. 1998: 101). The nature of the connections between these peripheral coastal regions separated by the topography of high cordilleras and the often inhospitable environmental conditions of the interior Meseta has been called one of the unanswered questions of Iberian archaeology (Aura et al. 1998: 101):

“Further research is clearly required along the valleys of the great rivers of the (Iberian) Peninsula, the Ebro, Duero, Tagus and Guadalquivir, as well as along the coastal plains of Galicia, western Andalucia and Algarve. Developments such as the recent discoveries of late Upper Paleolithic habitation sites in Cadiz León and Lugo and open-air rock art in the interior provinces of Segovia, Salamanca and Beira Alta, may help prehistorians forge the links of prehistoric social contacts that transcend the ecological differences among the peripheral regions, in a manner analogous to the artistic similarities between southern France and Cantabrian Spain on the one hand and Mediterranean Spain on the other.” (Aura et al. 1998: 101)

Working from the interior Meseta to the Mediterranean Coast, Cacho and Perez (1997: 272) looked at similarities of parietal art and saw the east-west river valleys as “natural passages to the coast” (“*pasos naturales hacia la costa*”).

This project uses a Geographic Information System approach to natural corridors. Necessary resources like chert and subsistence prey were neither abundant nor equally distributed in Mediterranean Spain across the Pleistocene-Holocene transition. These circumstances made mobility a crucial attribute for

successful hunter-gather adaptations. Therefore, GIS-based cost and time surface analyses, including GIS generated least-cost-paths, are “one of the most objective ways to determine routes and tracks that may have structured past hunter-gatherer landscapes” (Aubry et al. 2012: 530). This potential objectivity comes at the expense of particular or specific sets of circumstances. GIS cost analysis is a probabilistic approach to measures of travel time and distance, not an absolute approach (Aubry et al. 2012). As in arguments by analogy, GIS cost analysis is constrained by the degree to which its algorithms used to calculate time and distance map-on to the realities of human movement.

Since it is created by an objective series of probability statements, GIS cost analysis does not account for socially-defined hunter-gatherer territories (Cashdan 1983), although such factors can be used to weight the interpretation of results. The least-cost-path options that resulted from GIS analysis were selected based on whether they were associated with the demonstrated presence of human agency (i.e., rock art sites) (Aubry et al. 2012). Distances were measured in walking time not linear kilometers. Previous research by Aubry (et al. 2012: 532) suggests that distance as a measure of walking time in hours maps-on more closely to the cognitive conception of space in the Upper Paleolithic. To hunter-gatherers on foot an uphill kilometer in a rocky canyon was not the same as a kilometer on a level, open coastal littoral. But the distance that could be walked in the hours between first light and last – or before arrangements had to be made for approaching darkness – were and ever present reality that factored directly into decision-making.

Having a relatively efficient route (a least-cost-path) between the Mediterranean Coast and interior Meseta is not, on its own, a compelling reason to travel from coast to interior. Behavioral ecology suggests that at least the possibility of a net gain exists and that this possible net gain is sufficient to merit the time, energy, and risk expenditures invested in the journey (Foley 1985, Jochim 1983; Kelly 1995: 54-57, 1983; Winterhalder and Smith 2000). Behavioral ecologists have developed a set of assumptions to predict the investment strategies of late Pleistocene hunter-gatherers:

“One important assumption is that foragers optimize. Under such conditions, foragers should consider the search and pursuit costs (energy required to locate and capture prey) when deciding whether or not to use a given resource.” (Diehl 1997: 261)

In turn, optimization is assumed to result from hunter-gatherers making rational choices between behavioral alternatives, as those alternatives were understood based on the information available at the time (Kelly 1995: 54-57). Diehl (1997) has tested a model for determining the energy return rates per expended calorie for 200 kilometer hunting trips through upland areas versus local hunting. While Diehl was specifically concerned with subsistence in the early Holocene of the southwest region in North America, his variables closely map-on to the distance and topography of journeys from the coast of Mediterranean Spain to the interior Meseta at the Pleistocene-Holocene transition

Assuming Upper Paleolithic hunter-gatherers did make rational choices, these choices would have come within the context of past experiences about the

uncertainty of hunting as a subsistence enterprise. Frison (2004) is an archaeologist with direct experience in the uncertain nature of subsistence hunting, having grown up on the northern plains of North America during the Great Depression, and having continued to hunt throughout his adult life. Frison can be assumed to fully understand the diversity of risks factors determine the success or failure of each hunt. Well-planned hunts conducted under the best of circumstances are still never a sure thing:

“Expectations of success often go awry as a result of the unanticipated: the wind changes, predators are lurking nearby, birdcalls alert the animals to the hunter’s approach, or the hunter carelessly snaps off a branch. All of these can and often do disrupt a planned hunt; the hunter’s only choice is to initiate another attempt ...” (Frison 2004: 223)

“Further experiments soon confirmed that it requires a strong application of force from the atlatl spur to the proximal end of a dart shaft to achieve sufficient velocity ... The rapid body movement needed to accomplish this maneuver can cause an animal watching the hunter to quickly change its position. The time that elapses between the moment when the forward movement of the arm begins and when the projectile reaches its intended destination may be long enough to allow many animals to react swiftly enough to avoid the projectile. An added consideration is that the direction in which the animal will move is not always predictable. This claim is easily tested and proven: a deer that suddenly appears along the side of the highway may react to a moving vehicle in a number of different ways. It may continue its forward progress across the highway, or it may stop and let the vehicle go by, or it may reverse direction and retrace its steps, or it may stop and then suddenly try to cross in front of the vehicle, or it may move ahead a step or two and then reverse direction. Similar

reactions occur when the sudden appearance of a human hunter startles an animal.” (Frison 2004: 213-214)

We can assume that decision-makers for whom hunting was a way of life viewed every rational choice within the context of minimizing risk.

Abundance and prey-density of game animals affect the rates of return from hunting (Diehl 1997: 260). The possibility of hunting large herds of large herbivores on the open Meseta would have constituted a positive draw from the coast to the interior. Taking full advantage of large animals in large herds requires planning and preparation before the hunt, and a labor force sufficient to process the results of the hunt afterward (Frison 2004: 167-168, 225-227). These requirements are best met by communities of hunters – by a “temporary fusion of individuals from multiple social groups” (Hill 2007: 285; see also Hofman 1994: 286). Communal hunts in and of themselves are a form of aggregation (Hofman 1994), but they can also be the subsistence base for larger social aggregations (Bamforth 1991) – contexts for converting the largesse of good hunting luck into reciprocal debt obligations, through feasting or sharing, that can be redeemed in times of need or bartered in times of social friction.

Therefore, the potential social advantages of aggregation made possible by communal hunts also would acted as a positive draw to offset the costs of a group moving from coast to Meseta.

Kelly (1995: 54-57) views that optimization as a consequence of seeking out specific nutrients rather than general calories. The informant accounts in Speth and Spielmann (1983) and Wissler (1910) demonstrate that fat was a highly

valued currency of optimization, and fat is a product readily secured from large herbivores like those found on the Meseta.

In addition to the calculated potential energy gains from continuing to hunt horse and aurochs on the Meseta, when sea level rise inundated the coastal littoral and the herds there theoretically would have had to move to new ranges, risk minimization, social aggregation, and targeting fat as a specific nutrient will also be considered as factors in determining the potential gains to be realized by either logistic hunting forays or seasonal movement from coast to Meseta.

Lines of Evidence: Lithic Analysis

The third line of evidence followed by this project is a two-part lithic analysis. The first part of the lithic analysis relies on a quantified method pioneered by Barton (1998) and later refined by Barton and Riel-Salvatore (Riel-Salvatore and Barton 2004, 2007) as they further tested it with data from Riel-Salvatore's work in southern Italy across the Middle to Upper Paleolithic transition. The method uses curation, defined as an expression of economizing behavior, to link lithic assemblage composition and mobility-centered land-use strategies (Riel-Salvatore and Barton 2004: 257).

The frequency of retouched tools in an assemblage is plotted on a log scale against its total lithic artifact volumetric density, defined as the quantity of chipped stone per cubic meter of archaeologically excavated sediment (Riel-Salvatore and Barton 2007: 62). The resulting relationship is expected to be negative, since assemblages with high frequencies of retouched pieces will have lower overall densities of artifacts while assemblages with few retouched pieces

will tend to have higher densities. Barton and Riel-Salvatore argue that curated assemblages are associated with residential mobility, where the central locus of activity of a hunter-gatherer group changes frequently, and the less curated assemblages of logistically organized foragers result from the relative security of being more tethered to a known resource area (Riel-Salvatore and Barton 2004).

Assemblages deposited by task groups on logistical forays away from a central residential site can be expected to display high mobility patterns, since their extraction tasks also place a premium on leaving as little to chance. In cases of highly mobile hunter-gatherers – whether residentially mobile or task groups on logistical trips (*sensu* Binford 1980) – sites are occupied for short periods of time by groups who curated the chert they carried with them. The resulting low density assemblages will be characterized by relatively high frequencies of these curated (retouched) pieces (Riel-Salvatore and Barton 2004: 261):

... curated assemblages represent risk-minimizing strategies that aim to provide a constant supply of functional tools in times or places where they cannot be manufactured due to either lack of suitable material or preparation time (Bamforth and Bleed 1997) .” (Riel-Salvatore and Barton 2004: 261)

Curated assemblages result from relatively high frequencies of residential mobility in which hunter-gatherers moved their home base camp from resource patch to resource patch (Riel-Salvatore and Barton 2007: 62). Highly mobile subsistence strategies and situational variables such as lithic raw material distribution create conditions of *effective local lithic scarcity*, under which hunter-gatherers can be expected to conserve lithic resources by extending use-life

through regular maintenance (retouch). Expedient assemblages result from occupying a central site for prolonged periods of time while task-groups come and go to exploit non-local resources (Riel-Salvatore and Barton 2007: 62). Centrally tethered, logistic strategies create conditions of *effective local lithic abundance*, under which conservation measures are unnecessary, leading foragers to produce and discard more expedient pieces while investing little effort in extending use-life for any one piece. (Riel-Salvatore and Barton 2004: 260)

Barton and Riel-Salvatore's work emphasizes time-averaged suites of strategies resulting from palimpsest occupations, the predominant character of which will dominate the signature of a given archaeological assemblage. (Riel-Salvatore and Barton 2007: 62). Their use of the terms curated and expedient do not apply to individual site-occupation events.

The second part of this project's lithic analysis uses previous research at Cova de les Cendres (Villaverde et al. 1999) to suggest that Magdalenian groups using Cova de les Cendres were accessing at least one chert source near Alcoi (Villaverde et al. 1999: 24) in La Marina Alta, an area of mountain valleys that served as natural corridors (Aura Tortosa et al. 1993) connecting the Mediterranean littoral with the southeastern edge of the interior Meseta. Visual identification places the source of this chert at La Umbria, east of Alcoi (Eduard Faus Terol, Centre d'Estudis Contestans, personal communication, 2012). Chert from La Umbria has also been identified from at least one Magdalenian-related area near Villena on the southeastern edge of the Meseta (Eduard Faus Terol, Centre d'Estudis Contestans, personal communication, 2012). While this alone

does not place Magdalenian hunter-gatherers from Cova de les Cendres on the southeastern edge of the Meseta, it does indicate that a group on the Meseta near Villena accessed chert from the same raw material source as Magdalenian hunter-gatherers from Cova de les Cendres.

CHAPTER 3
THE PLEISTOCENE-HOLOCENE TRANSITION
IN MEDITERRANEAN SPAIN

As global sea levels rose from their low point at the Last Glacial Maximum to current levels in the early Holocene, Mediterranean Spain lost nearly 74% of its coastal littoral (Figure 4) changing the physical geography of subsistence and creating a human landscape of principled uncertainty for hunter-gatherer social groups in the region.

The primary variables from an archaeological perspective are timing and value: How fast did mean sea level rise in the Mediterranean across the Pleistocene-Holocene transition? And what subsistence value can be placed on the lost terminal-Pleistocene biomass that was inundated by saltwater?

Sea Level Rise

The role sea level changes have played in the deposition of the archaeological record and post-deposition alterations to the archaeological record has not fully been taken into account by much of archaeological research in Europe. This is especially relevant to the archaeology of Pleistocene-Holocene transition, during which a widespread influx of glacial meltwater caused by global warming raised sea levels up to 120 meters (Straus 1996a).

“Much modern archaeological thought has emphasized the need to interpret prehistoric activity in terms of available resources. This implies an ability to reconstruct the environments of the past. We believe that in this process the magnitude of the differences between present and past

environments has often been seriously underestimated, and that thus the past has continued to be viewed through the present. The issue is illustrated by the late Quaternary sea-level changes that altered the shores of the world to a degree not always fully appreciated by archaeologists whose interpretations of prehistoric activity frequently appear blinkered by present-day topographical constraints. We present ... as a case in point the late Quaternary coastal paleogeography of the central and Western Mediterranean ...

“Each of the glaciations of the last several million years has caused sea level to drop as water was stored in ice-caps on the continents. The fact itself is well known, but only for the last glacial maximum ca. 18,000 years ago are we able to assess with some confidence the extent of the geographic change ... Paleogeographic maps, even for this recent time are rare ... Consequently, the extent of the regional or local changes in coastal geography is often underestimated in archaeological interpretations. Even less commonly is it realized that the lands emerging or being inundated were of a type – a level coastal plain – that may scarcely be represented in the present coastal zone.”

(Shackleton et al. 1984: 307-308)

Research in Mediterranean Spain recognizes variations in the coastline as one of the “only manifestations of significant bioclimatic changes” (Aura et al. 1998: 97) directly attributable to the Pleistocene-Holocene transition, but the full extent and the specific effects of these coastline changes are not yet incorporated into explanations. The Mediterranean shore line located approximately minus-100-meters to minus-120-meters below the present mean sea level at 18,000 years before present (the generally accepted date for the Last Glacial Maximum that originated with CLIMAP 1976) is said to have undergone a constant rise

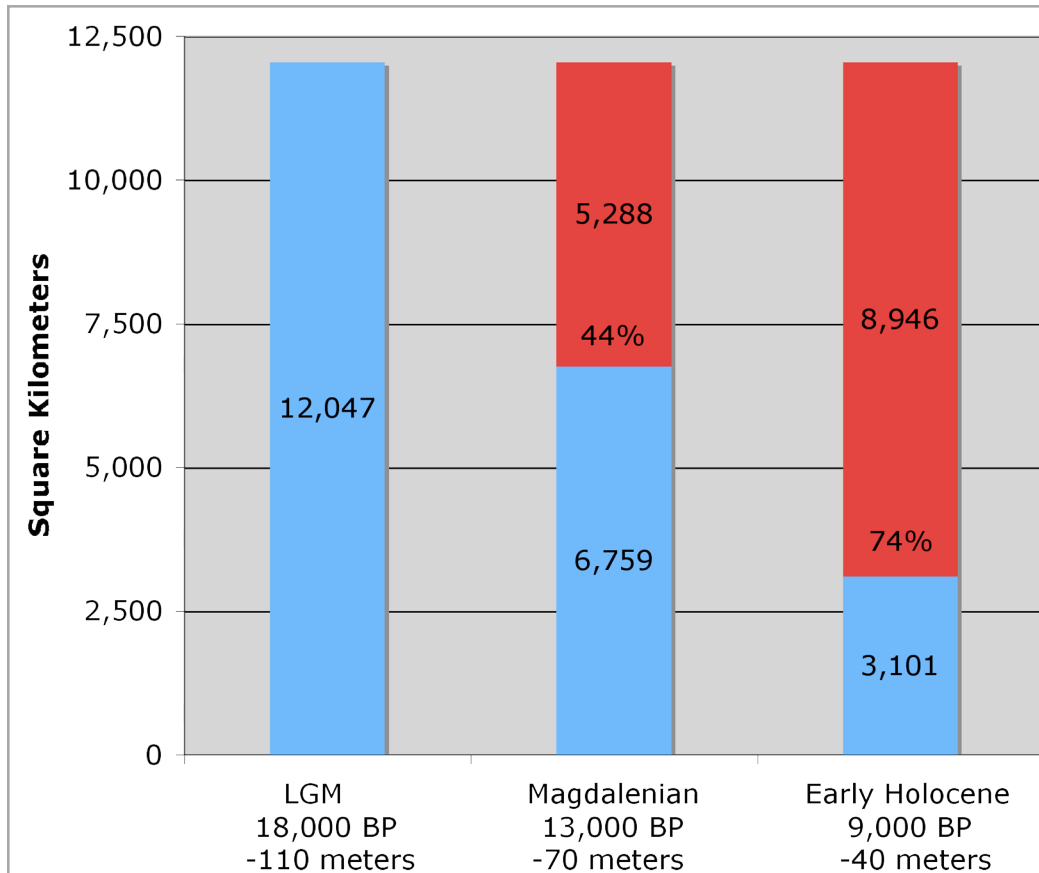


Figure 4. Littoral Inundation from the Last Glacial Maximum to the Early Holocene in Mediterranean Spain.

■ Littoral landmass ■ Landmass inundated
Values given in square kilometers.

up to -40 meters (minus-40-meters) below the current mean sea level at about 9000 years before present with the flooding of the continental margins described as progressive (Aura et al. 1998: 97). However, evidence from reconstruction models based on the full range of available data suggests that changes in sea level were neither constant nor straightforward.

Sea level maximums for specific periods can be recreated using uranium-series dating and electron spin resonance dating of fossil coral reef terraces and cross-referencing the results against global sea level estimates based on analysis

of deep sea oxygen isotope ratios at millennial scale resolutions or higher (Siddall et al. 2003: 853). Relatively well dated fossil coral reef terraces are distributed throughout the world's tropical seas. For example, the chronostratigraphy of uranium-series dated Pleistocene (circa 125,000 bp) reef terraces from Barbados in the West Indies has been cross-referenced for consistency against the oxygen isotope record of deep sea core V28-238 from the Solomon Plateau in the equatorial Pacific (Bender et al. 1979).

More recently, Siddall (et al. 2003) studied the extent of changes in global sea level associated with climate fluctuations of the last glacial cycle using coral reef terraces in the Red Sea and cross-referenced the results against an oxygen isotope analysis from a high resolution resampling of GEOTUE-KL11, a central Red Sea core. The Red Sea's only water-exchange access to the open ocean – the Strait of Bab el Mandab – is both narrow (18 kilometers wide) and shallow (137 meters deep). This combination increases the Red Sea's sensitivity to sea level changes. For comparison, the Strait of Gibraltar – the only water-exchange access for the Mediterranean Sea is 14.3 kilometers wide at its narrowest point with a depth ranging from 300 meters to 900 meters. Comparing Red Sea reef chronostratigraphic data to a high resolution oxygen isotope analysis also from the Red Sea (comparing like to like) allowed for a degree of precision in the reconstruction that reduced the uncertainties for previous studies from the range of ± 30 -meters to accuracy within ± 12 -meters (Siddall et al. 2003: 853-854). There is one somewhat ironic exception to this level of precision. The Red Sea has no oxygen isotope record for the period from the Last Glacial Maximum

(LGM) (~18,000 years bp) to the onset of the Younger Dryas (~12,700 years bp), which precludes applying sea level data from the Red Sea directly to all but about the last millennium of the Pleistocene-Holocene transition. The omission is related to excessive salinity of 49 to 50 psu (practical units of salinity) that exists in the Red Sea when intervals severe glacial maxima restrict available inputs of freshwater into the world's oceans, a condition to which the Red Sea also has a heightened sensitivity (Siddall et al. 2003: 855). The Siddall team's work in the Red Sea focuses on the periods from 75,000 bp to 25,000 bp (calibrated) and the onset of the Younger Dryas to the present, which bracket the Pleistocene-Holocene transition (Figure 5) and permit an indirect cross-check of coral reef derived sea level data at the increased ± 12 -meters level of resolution.

The result (Siddall et al. 2003: 855) found a maximum rate of sea level change in the Red Sea to be 0.02 meters per year (2 cm yr^{-1}). This is equivalent to the mean rate of change during the last deglaciation and places the mean rate of change in the Mediterranean Sea at 20-meters of rise for each 1000 year interval.

Therefore, the estimated rates used to estimate littoral landmass loss in Mediterranean Spain (Figure 4) are conservative when compared to the reconstruction values from the Red Sea. If the estimated landmass loss is in error, it errs in being an underestimate of the actual loss. A discussion of the variable inputs used in making these estimates follows in Chapter 4.

Receding Ice Sheets

Assuming a geologically solid earth, sea level is a function “determined by the gravity of the surface load of ice and redistributed meltwater such that the sea-

surface remains at constant gravitational potential” (Lambeck and Purcell 2005: 1973). The reality is that the earth surface underlying the oceans is deformable, and sea level also incorporates the geological structure at the specific local measured. Although the volume of water expands as it is converted to ice, the weight remains a relative constant – tons of ice can be converted to cubic meters of water. One ton of water/ice rounds off to 1.02 cubic meters of water or about a 1:1 ratio (Volume Conversions 2012). Therefore, tons of ice and cubic meters of water are comparable.

A 20-year study ending in 2011 shows that the Antarctic and Greenland ice sheets, the two largest ice sheets on earth, have accelerated the pace at which they lose ice mass (Rignot et al. 2011) and are becoming the dominant contributor to global sea level rise faster than existing models predicted. Since records began being kept on the Greenland ice sheet in 1979 (Science Daily 2011), the three years of most extensive ice melting occurred in 2007, 2010, and 2011. None of these years marked a temperature extreme, but all three years fall in the later stage of a warming cycle. This indicates that glacial melt cycles can become self-amplifying. When ice is covered by snow, it melts more slowly. Being lighter in color, white snow reflects the more of the sun’s energy resulting in a higher albedo effect. Albedo describes the amount of solar energy absorbed by a surface (Science Daily 2011): higher albedo surfaces absorb less solar energy, so ice covered by snow melts more slowly than a naturally darker bare ice sheet. As the mass balance, the amount of snow gained minus the snow and ice that melts, decreases, ice sheets become less likely to hold significant snow, and

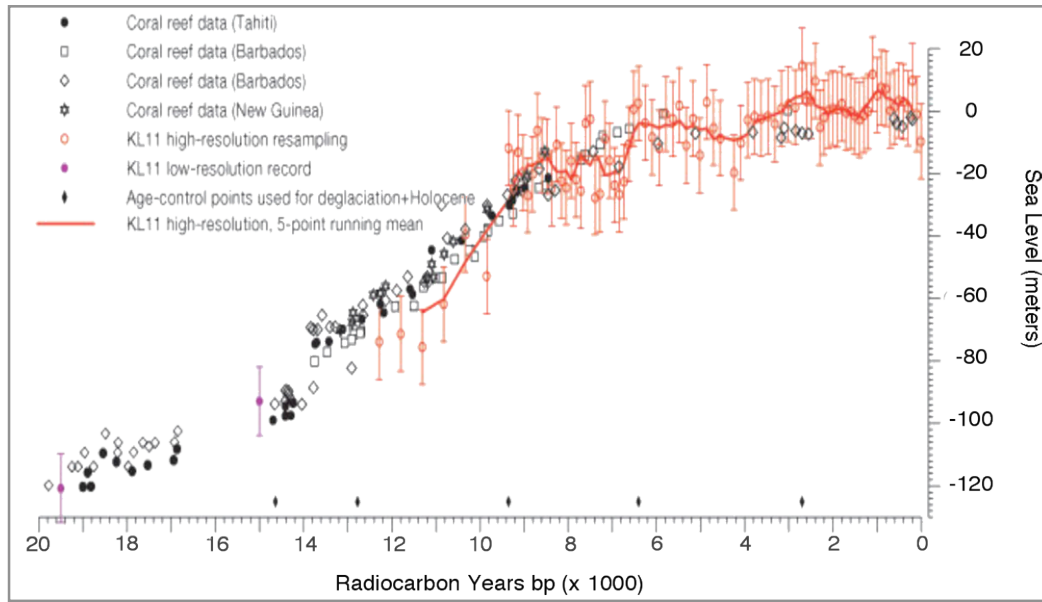


Figure 5. Sea level reconstruction based on $\delta^{18}\text{O}$ record from core KL11 ($18^\circ 44.5' \text{ N}$, $39^\circ 20.6' \text{ E}$ / $37\text{Q } 536191\text{mE } 2072278\text{mN}$), including 12 meter error bars. Chronology is based on **calibrated** AMS radiocarbon datings. Record zeroed to modern sea level by removing the mean KL11 record for the past 7,000 years.

(After Siddall et al. 2003: 854, Figure 1)

glacial melt becomes self-amplifying. The Greenland ice sheet lost 192 million to 258 million tons of ice each year from April 2002 to April 2006 – equivalent to a volume loss of 212 km^3 to 284 km^3 (Murray 2006). Based on data from 2003 to 2008, the average trend of Greenland ice loss is about 195 cubic kilometers per year (Science Daily 2008).

Modern studies on annual or decadal time-scales like the Antarctic and Greenland studies must be treated with caution when applied to long-term processes like the Pleistocene-Holocene transitions. However the accelerating pace and self-amplifying nature of the modern studies above do suggest that sea

level rise from melting ice sheets during the Pleistocene-Holocene transition would not have been constant or progressive. The Younger Dryas, from about 12,800 years before present to 11,500 years before present (Muscheler et al. 2008), instituted an abrupt return to previous glacial conditions and with conditions favorable to snow accumulations for a millennium would have halted the self-amplifying ice melt.

The effects of massive ice sheets at the Last Glacial Maximum were almost exclusively a Northern Hemisphere phenomenon (Broccoli and Manabe 1987). The process by which the ice sheets receded and contributed meltwater to the oceans also occurred in the Northern Hemisphere but resulted in a global rise of mean sea level. The acceleration and deceleration of the overall pace in this process was punctuated at intervals by natural events that led to surges of meltwater entering the ocean system. When two ice lakes covering a combined surface area of more than 750,000 square kilometers were breeched and flooded into the Atlantic, the effect may well have been a critical tipping point leading to the onset of Younger Dryas cooling period (Vaikmäe et al. 2001: 169). These sudden freshwater influxes created cold pulses that are thought to have caused a temporary waning of the North Atlantic conveyor current as it transported and distributed sun-warmed water toward the pole (Vaikmäe et al. 2001: 169). The largest of these ice lakes, Lake Agassiz in North America, was formed by freshwater from the retreating Laurentide ice sheet and covered more than 400,000 square kilometers between the Canadian provinces of Manitoba and Ontario and the U.S. states of Minnesota and North Dakota (Hostetler et al. 2000;

Fisher 2003). But it is the Baltic Ice Lake draining into the North Atlantic adjacent to continental Europe that most directly affected sea level changes in the Mediterranean Sea.

The initial ice advance leading to the Last Glacial Maximum began about 25,000 years before present reached its maximum extent between 20,000 years and 18,000 years before present. This glacial advance did not involve La Marina Alta or Mediterranean Spain, except to lock-up freshwater in ice that had previously been available to Europe's precipitation system and create a cycle of aridity, mainly evidenced in pine forest becoming open oak parkland (Badal 1990; Badal and Carrión 2001; Carrión et al. 1999; Carrión et al. 2003; Carrión and van Geel 1999). However, the retreat of that same ice greatly influenced human adaptive responses in La Marina Alta and Mediterranean Spain.

Having reached its maximum extent, the Fenno-Scandinavian ice sheet, the Northern European equivalent of the Laurentide ice sheet in mass and effect, began retreating slowly. By 16,000 years before present (Davydova et al. 2001; Lundqvist and Wohlfarth 2000; Widerlund and Andersson 2011) the edge of the retreating ice roughly bordered the present-day Baltic Sea. Meltwater formed extensive lacustrine systems still visible in the topography of northern Russia, Poland and Germany (Davydova et al. 2001). By about 14,500 years before present, the Baltic Ice Lake had formed in post-glacial moraines that appeared as the isostatic rebound of land surface freed from the weight of the ice sheet rose and blocked the Öresund Strait between present-day Copenhagen, Denmark and Malmö, Sweden. At its maximum about 12,000 years bp the Baltic Ice Lake held

an estimated 330,000 cubic kilometers of water – approximately one-tenth the current volume of the Mediterranean Sea – and rose tens of meters above sea level. As retreating ice uncovered a lowland area near Mount Billigen, the low-lying topography and a lack of isostatic rebound allowed more than 7,000 cubic kilometers of water (University of Gothenburg 2010) to discharge about 12,700 years bp (Bergsten and Nordberg 1992). Once the Mount Billigen breach emerged, the volume of meltwater flow gouged and widened the channel, increasing the rate of discharge. The drainage route remained unchanged until about 10,800 to 10,300 years before present, based on varve deposits, when another passage opened in south central Sweden, through which the Baltic Ice Lake continued to discharge until it reached a state of equilibrium with sea level in the Atlantic Ocean (Andrén et al. 2002; Jiang et al. 1998; Bergsten and Nordberg 1992).

Last Glacial Maximum

At the low sea level mark of the Last Glacial Maximum (about minus-120 meters of current mean sea level), the geological structure of the Straits of Gibraltar narrowed, decreasing the rate of exchange between the Atlantic Ocean and the Mediterranean Sea (Vaikmäe et al. 2001: 182). As sea level rose in response to the general process of glacial melt in the Northern Hemisphere and the sudden surge of meltwater from the Baltic Ice Lake into the North Sea directly adjacent to the Atlantic Ocean, the rate of exchange into the Mediterranean increased as sea level rose to reach a wider gap at the Straits of Gibraltar even as the amount of water available to exchange also increased. The Mediterranean Sea

has a small, well-defined tidal range, where the observational evidence of inundation can be related directly to mean sea level (Lambeck and Purcell 2005). Observed evidence indicates that surficial water from the Atlantic is the most important sea level control in southeastern Iberia (Vaikmäe et al. 2001: 183). The rate of shoreline displacement is a function of surficial water from the Atlantic Ocean input into the Mediterranean Sea (Zazo et al. 1994). Farther south, on the northwest margin of Portugal's continental shelf, studies indicate that sea level rose 30-meters to 40-meters (when compared to current mean sea level: from a range of minus-130 to minus-140-meters rose up to minus-100-meters) during the initial phase of deglaciation between 16,000 and 13,000 years before present (Vaikmäe et al. 2001: 183), which includes the early Magdalenian period of Mediterranean Spain. The rate of sea level rise on the northwest Portuguese coast increased as the Magdalenian progressed, trending upward another 60-meters between 13,000 and 11,000 years before present (from minus-100-meters to minus-40-meters compared to current mean sea level) during the Pleistocene-Holocene transition (Vaikmäe et al. 2001: 183). It is important to note that these are open waters in the Atlantic Ocean not limited by the Strait of Gibraltar.

Fluctuations of sea level in the Mediterranean Sea also produced important ancillary effects that would have influenced changes in the biomass of the coastal littoral. When sea level fell to its lowest level at the Last Glacial Maximum, groundwater flow increased in the coastal aquifers as hydrostatic counter-pressure from the volume of water in the Mediterranean Sea fell to comparably low levels (Vaikmäe et al. 2001: 177). This increased the presence of freshwater on the

Mediterranean littoral. Conversely, in the Llobregat Delta system on the Mediterranean coast southwest of Barcelona, marine sea water flowed into the aquifer as sea levels rose (Manzano et al. 2001: 107). Progressive increases in upstream freshwater eventually flushed the sea water back toward the Mediterranean Sea but not until the interval from 8000 to 6000 years before present. From approximately 13,000 to 8000 years before present, biomass on the Mediterranean coastal littoral had to deal with or retreat from an increase in groundwater salinity.

The strong thermal gradient in the Atlantic Ocean that separates the warmer waters of the Gulf Stream from the colder polar water mass shifted south to about 42° north latitude – comparable to the northern Atlantic Coast between Spain and Portugal – during the low sea level of the Last Glacial Maximum. As glacial meltwater flowed into the Atlantic Ocean, surface water temperature fell from about 12° Celsius to about 4° Celsius as the cyclones neared the area of water being exchanged between the Atlantic Ocean and the Mediterranean Sea (Vaikmäe et al. 2001: 167). As the ambient climate warmed markedly after about 14,000 years before present (Vaikmäe et al. 2001: 167), the temperature of water exchanged from Atlantic Ocean to Mediterranean Sea and drawn east along the coastal littoral of southeast Spain by a strong current (Aura et al. 2010) dropped to 8° Celsius in reaction.

Evidence from the early Holocene in the southern North Sea shows that coastal and saltmarsh vegetation communities formed temporarily during periods of coastline retreat and rapid sea level rise (Shennan et al. 2000: 317). Similar

temporary saltwater adapted vegetation communities developing along the coast of Mediterranean Spain should be considered a precursory form of inundation from the perspective of Magdalenian hunter-gathers in Mediterranean Spain. Subsistence prey adapted to the coastal littoral plain would have been required to migrate away to freshwater grasslands farther inland. The littoral landmass available as saltmarsh prior to outright inundation was not the same habitat that had supported economically important subsistence prey.

Indications exist of geological events that possibly affected the distribution of increased water volume and directed rising sea level toward the Mediterranean coastline prior to or early in the Pleistocene-Holocene transition.

The Balearic Abyssal Plain (40°00'N, 01°30'E / 31T 371957mE 4428834mN) is located east of the Balearic Islands – Majorca, Minorca, Ibiza and Formentera – about 100 kilometers off the current coastline of Mediterranean Spain and about 70 kilometers north of the city of Valencia (Rothwell et al. 1998). Abyssal plains are smooth, flat areas on the deep ocean floor, usually between 3000 and 6000-meters deep. The southern edge of the Balearic Abyssal Plain lies at a depth of 2800 meters, one of the deepest points in the Western Mediterranean, which is divided from the Eastern Mediterranean by a sill between the island of Sicily and Tunisia on the North African coast that reaches a maximum depth of only 400-meters (Rothwell et al. 1998, 2006).

At about 22,000 years before present, the lowest point of sea level during the Last Glacial Maximum, the upper ridge bordering the southern Balearic Abyssal Plain gave way creating a massive turbidite (underwater landslide) that

deposited an estimated 600,00 to 500,000 cubic kilometers of sediment over 77,000 square kilometers of the basin floor (Rothwell et al. 1998: 377; Rothwell et al. 2006). Dated by a series of accelerator mass spectrometry readings in five widely spaced cores from above the bed and at the base of the bed, the magnitude of the turbidite is the main sedimentation event on the Balearic Abyssal Plain over the past 100,000 years (Rothwell et al. 1998: 377).

As a comparison, the Storegga turbidite, 100 kilometers off the west coast of Norway at Sula, one of the largest submarine slides discovered, occurred 8150 years before present (about 7300 radiocarbon years ago) and deposited between 2500 and 3500 cubic kilometers of sediment (Grauert et al. 2001; Bondevik et al. 2003; Bryn et al. 2005). The slide generated a tsunami surge that ran up 10 to 12 meters when it hit the west coast of Norway. The surge on land was as high as 20 to 30 meters in the Shetland Islands and reached as far as Scotland, where the surge run up was four to six meters (Grauert et al. 2001).

The Dogger Bank

The lasting effect of the Storegga Slide tsunami is that it catastrophically flooded the Dogger Bank, the landmass that had connected Great Britain to continental Europe since the Last Glacial Maximum. The Dogger Bank was a human inhabited landscape during the Late Paleolithic and early Mesolithic, including the interval of tsunami inundation (Weninger et al. 2008). In addition, applying lessons from the archaeological record of Northwest Europe indicates that human groups would not have been evenly or randomly spread throughout the Dogger Bank. Population density would have been greater in areas with

access to coastal, lacustrine and riverine resources (Fischer 1997).

“Since it is precisely the coastal and near-shore riverine areas (the latter because of a funneling effect up coastal river valleys) that would have been most affected by the Storegga tsunami, there may have been considerable impact on the contemporary population.

“(I)t can be suggested that some 700 to 3000 individuals were affected. This number is sufficiently large to have potentially resulted in the extinction of a number of local bands ... This does not necessarily imply that all were killed immediately, although given the likely rapidity and scale of the event, a significant number of people would almost certainly have been caught and drowned by the inexorably rising waters, while many others would have been displaced. Nor would the consequences be limited to the wave’s immediate impact, as productive coastal areas could have been devastated.”

(Weninger et al. 2008: 14-16).

The important lesson from the Dogger Bank is the description of how the flooding occurred: lowest lying areas first – the coastal littoral plains, the river valleys (used as natural corridors in La Marina Alta), the salt marshes, and the freshwater aquifers. Coastlines are like deserts in terms of human adaptation. They are organized around the availability of freshwater.

With saltwater from the Mediterranean running up rivers and flooding into freshwater aquifers increasing the presence of brine even as the outflow recharge of freshwater is hindered until a critical mass is reached and even though the denser saltwater tends to underlay freshwater pushing it toward the upper strata, a point is reached where a greater percentage of freshwater is in direct contact with saltwater than is kept separate and the two begin to mix. Known as the Ghyben-

Herzberg relation after the two European scientists who independently calculated it in the late 19th century and early 20th century (Barlow 2003), the equation expresses the relationship of freshwater in an unconfined aquifer (a water table) to intruding saltwater based on the balance of the height of two columns of fluids with different densities (Barlow 2003). The Ghyben-Herzberg relation states that for every foot of fresh water in an unconfined aquifer above sea level, there will be forty feet of fresh water in the aquifer below sea level. Freshwater has a density of about 1.000 grams per cubic centimeter at 20° Celsius, but the density of seawater is about 1.025 grams per cubic centimeter at 20° Celsius.

There is a tipping point at which the rise in sea level causes saltwater to displace freshwater farther and farther inland. By definition, water remains water (in its liquid state) all along the range of temperatures between 1° Celsius and 99° Celsius. But within one-degree in either direction water crosses its tipping point and changes states: to a solid as ice or to a gas as steam. On the coast of La Marina Alta, the central area of Mediterranean Spain, where the Serpis River flows into the Mediterranean Sea at Gandia, the Girona River at Dénia, and the Gorgos River at Xàbia, tipping point in the displacement of freshwater by saltwater would have resulted in plains of annual grass salt flats. Evidence from the Colorado River delta in the Gulf of California suggests this process can be completed in a human lifetime (Leopold 1949).

The effect does not require sea level to rise to a point at which saltwater inundates the landscape and physically floods hunter-gatherer landscapes, as happened when the Storegga Slide tsunami struck the Dogger Bank about 8200

years before present. But the outcome is similar. When freshwater dependent biomass is overwhelmed by saltwater flowing up river mouths, replacing the reservoirs of groundwater aquifers, and increasing the soil salinity of coastal grass plains, the biomass migrates to the next available freshwater ecosystem.

Effects of Salinity on Freshwater Ecosystems

In the Eastern Mediterranean, groundwater salinization during the early Neolithic affected the region around Jericho on the western side of the lower Jordan Valley, about ten kilometers northwest of the Dead Sea, where salinity is ten-times greater (~33%) than salinity in the Mediterranean Sea (~3%) (Lange et al. 2008). Groundwater salinity wicking to the surface of intensely used agricultural fields appears to have led to the initial collapse of Jericho in the Pre-Pottery Neolithic A, about 9500 years before present (Bar-Yosef 1989).

While the effects of increasing salinity on freshwater ecosystems is fairly straightforward, the rate at which coastal littorals of the Mediterranean Basin reached their critical mass during the Pleistocene-Holocene transition is less clear-cut. Calculating actual inundation is more straightforward. The Pre-Pottery Neolithic village of Atlit-Yam, circa 8100 years before present, on the Mediterranean Coast about 10 kilometers south of the modern-day port city of Haifa, Israel. Sandstone ridges parallel to the present coastline inhibited drainage and created a coastal plain characterized by swamps. Changes in precipitation patterns caused by the Pleistocene-Holocene transition in combination with episodes of tectonic tilting caused freshwater swamps in the vicinity of Atlit-Yam to dry up rapidly (Galili et al. 1993: 134), which created favorable conditions for

coastal settlement. The faunal assemblage at Atlit-Yam consists of 322 NISP with dominant percentages of wild goat (*Capra*, 45%) and aurochs (*Bos* 43%). Exceptional bone preservation allowed morphological and metrical confirmation that these remains represent wild species of goat and cattle and not domesticated variants (Galili et al. 1993: 147-149). The main contributing factor to this ungulate largesse was the freshwater aquifer captured in the coastal sandstone (called eolianite or kurkar) bordering the site (Galili and Nir 1993: 268). Apparently encouraged by the numerous natural freshwater springs in the area of the kurkar ridge landward of the village, the people at Atlit-Yam dug a functioning well 1.5 meters in diameter and 5.7 meters deep, which they lined with stone (Galili and Nir 1993: 265).

What makes Atlit-Yam and its well noteworthy is that the village is currently located 400 meters off the shoreline, submerged eight to 12 meters below Mediterranean sea level. The region's Pleistocene aquifer drains from the foothills to the Mediterranean coastal plain in a steady-state flow. "Every change in sea level influences and is reflected in the groundwater level: a sea-level rise results in a rise in the groundwater table on the one hand, and its possible salinization on the other. Coastal wells can therefore supply freshwater long the level does not change drastically" (Galili and Nir 1993: 267).

"The history of the site, its well, and the desertion phenomena prove that sea level rose at a high rate during the Neolithic period (c. 9500-7000 BP), until the end of the post- last-glaciation transgression, some 6500-6000 BP. Given tectonic stability, and since the bottom of the well is at about 15.5 m below present sea level, sea level would have been

at least 16 m below the present level during the well's first stages, and at about 8 m below the present level after the village was completely inundated. Based upon radiocarbon assays, this village was occupied for approximately 350-400 years. During this time the sea level rose approximately 8 m. Average sea-level rise, based on the above figures, was therefore of the order of 20 mm yr^{-1} for the first period, until the desertion of the village.” (Galili and Nir 1993: 269).

The 20 mm yr^{-1} average rate of sea-level rise at Atlit-Yam is the same maximum rate of sea level change (Siddall et al. 2003: 855) identified in the Red Sea – 2 cm yr^{-1} .

Average sea-level rise for the Eastern Mediterranean based on radiocarbon dates from a human habitation site helps to confirm expectations for the rate of coastal inundation. But the well at Atlit-Yam may also provide useful information. The bottom of the well contains sandstone chunks embedded in sandy clay suggesting that as sea level rose and saltwater entered the bottom of the well, early Neolithic villagers tried to decrease the mixing of saltwater with freshwater by infilling the lower, more saline, parts of the well (Galili and Nir 1993: 269; Goring-Morris and Belfer-Cohen 2010: 74). Given the difference in densities, groundwater would have risen as denser saltwater entered the well and pushed up the freshwater column. By artificially raising the level of the column with infilling, the water column would have been defined by the 1.5 meter diameter of the well shaft, increasing the potential for separating freshwater from saltwater based on specific density. However bones and other rubbish above the intentional infilling indicates the attempt to keep pace with sea level rise was

unsuccessful and the abandoned well became a midden. The effect of rising sea level inundated the freshwater aquifer about a millennium before actual sea level rose to inundate the land on which the village of Atlit-Yam was built. It was not until about 6500 to 6000 years before present, that the Mediterranean Sea flooded inhabited portions of the coastal plain.

Perhaps the most accurate calculation of rate of land loss to physical inundation from the Mediterranean Sea also uses data from the Eastern Mediterranean. This set of characteristics carries the proviso that the effects of saltwater intrusion and increased salinity transmitted through groundwater aquifers and the lowest lying topography of coastal littoral plains are realized well in advance of land lost to rising sea level. Turney and Brown (2007: 2040) have been able to use the “2006 National Geophysical Data Center Global Digital Elevation Model (ETOPO2) that represents gridded (2 min by 2 min) elevation and bathymetry for the world (www.ngdc.noaa.gov/mgg/image/2minrelief.html) to explore possible links between sea level rise and transmission of the Neolithic from the Near East (the Eastern Mediterranean) to continental Europe. By reprojecting the ETOPO2 dataset onto an equal area projection and determining the areas of contours set at 155, 30 and 28.6 mean base sea level (mbsl), their data helps to establish parameters for identifying the portion of the overall coastal littoral plain in the Mediterranean Basin that would have been available to Terminal Pleistocene and Initial Holocene hunter-gatherers and to establish expectations for the rate at which sea level rise resulted in the loss of littoral land mass to inundation by the Mediterranean Sea. The last of the Laurentide Ice

Sheet in North America collapsed between 8740 and 8160 years before present (Barber et al. 1999) and caused the largest North freshwater pulse in the North Atlantic during the past 100,000 years (Clarke et al. 2003). In turn, this post-glacial freshwater pulse raised global sea levels and estimated 1.4 meter (Clarke et al. 2004). According to Turney and Brown (2007), precision radiocarbon dates from mollusk shells put the breach of the Eastern Mediterranean's Bosphorus Sill (currently 30 meters below Mediterranean Sea level) and the subsequent saltwater flooding of the previously freshwater Black Sea at between 8350 and 8230 years before present. Using this 120 year interval to represent the fastest rate of Holocene global sea level rise (Turney and Brown 2007: 2038) – during which time the eastern Mediterranean lost an estimated 1100 square kilometers of landmass to inundation and the entire Mediterranean Basin an estimate 4022 square kilometers.

It is important to re-emphasize that coastal littorals in the Mediterranean Basin were (and still are) differentially susceptible to inundation. A 1.4 meter rise in global sea level does not result in 1.4 meters of coastal plain lost to saltwater flooding. Relative sea level change at any given location is a function of changes in global ice volume *and* the response of that site's geological structure to accept the surface loading of additional water volume (Tuccimei et al. 2011) – especially large inputs of water volume from pulses like the opening of the Baltic Ice Lake (see above), which stored glacial melt from the Fennoscandian ice sheet that covered much of continental Europe and the last of North America's Laurentide ice sheet stored in Lake Agassiz. In some areas of land mass covered by the

Fennoscandian ice sheet, the isostatic rebound as weight of the retreating ice was removed more than kept pace with the sea level rise associated with the melting ice, and relative elevation above sea level on some coastlines increased as global sea levels rose (Fjeldskaar et al. 2000).

Assuming the interpretation of data from Atlit-Yam are accurate (Galili and Nir 1993; Galili et al. 1993) – that the Pre-Pottery Neolithic B period residents of a single-phase village dug a 5.7 meter deep well into their sandstone based aquifer, then as sea level continued to rise added sandstone chunks to the bottom of the well in an effort keep the lighter density freshwater column above the intruding, denser saltwater, and finally abandon the well all together using it instead as a midden.

Also assuming Turney and Brown (2007) are correct that the last outflow of glacial meltwater from the Laurentide ice sheet in North America (the breaching of Lake Agassiz) produced a global sea level pulse that flooded 1100 square kilometers in the Eastern Mediterranean and 4022 square kilometers in the total Mediterranean Basin, in one 120 year interval of the early Holocene.

Then it is important for this study of hunter-gathers in the Western Mediterranean during the Pleistocene-Holocene transition to determine the effect of sea level rise from the Last Glacial Maximum (Rothwell et al. 1998: 377; Rothwell et al. 2006), through Baltic Ice Lake breach at about 12,500 years before present (University of Gothenburg 2010; Bergsten and Nordberg 1992), to the initial onset of the Holocene at 11,700 years before present (IUGS 2008a).

CHAPTER 4

THE IMPACT OF COASTAL LITTORAL INUNDATION IN MEDITERRANEAN SPAIN

As the importance of Mediterranean Spain to our understanding of early Holocene adaptations and the spread of European domesticated economies became clear (e.g. Miller et al. 2009; Miller et al. 2008; Barton 2004; Barton et al. 2004; Barton et al. 1999), archaeology in the region took its rightful place in the international discussion and, having to go back and explain to bring the international community up to date, became more holistic in its approach to the data. This process seemed to coalesce around Villaverde, Aura, and Barton's seminal review of current evidence for the Upper Paleolithic in Mediterranean Spain (Villaverde et al. 1998), although precedents had been set earlier by Davidson (e.g., 1976a, 1976b, 1983, 1986, 1989) and Villaverde (Villaverde Bonilla and Fullola Pericot 1990). Spanish archaeologists began publishing more in other languages and international journals (e.g., Aura et al. 2002, 2005, 2007, 2009, 2010, 2011; Carrión 2001a, 2001b, 2002; Villaverde et al. 2012) and as members of international research teams (e.g., Aura et al. 1998, 2002; Barton et al. 1999, 2002, 2004aa, 2004b; Carrión et al. 1997, 1999, 2008).

In re-examining the regional synthesis for Mediterranean Spain, the effects of sea level rise were acknowledged without being directly integrated into interpretations of systematically excavated materials from discreet sites, primarily caves and rock shelters.

“During the early Holocene, the sea level rose again to 40 m below msl by ca. 9000 B.P. (Shackleton and van Andel, 1985). With a local rate of sea level rise of around 1 cm/year, the postglacial transgression submerged the continental shelf, causing the coastline in some areas to retreat to the edge of the upland zones mentioned above and narrowing the coastal plain in others—although the details of this process are difficult to assess due to the geologic variability in the continental margins in this zone.”

(Villaverde et al. 1998: 126-127)

“(T)here is a tendency for lithic raw materials to be collected in smaller areas, related to technological changes and probably to restrictions in the scope of annual exploitation territories. Figurative art also disappears at this time (though highly localized geometric motifs are common in both the final Magdalenian and Azilian). These phenomena might all be related to ever greater restrictions in the ranges over which individuals sought their mates, as groups saw their territories shrink in the face of reforestation, sea-level rise and relative increases in human population packing.” (Aura et al. 1998: 95)

As secure evidence from systematic excavations continued to accrue, conditions that possibly affected the patterning of Late Upper Paleolithic assemblages drew more attention:

“Sites located currently next to the coast include: Cova de les Cendres (Alicante) ..., Volcán del Faro (Valencia) ...; or near the coast, Cova del Blaus y Cova de Matutano (Castellón) ... During the late Upper Pleistocene, the sea was 30 to 50 km further away from the shore. The sites are located in flat shore areas where marshes and lakes were common (Cova de les Cendres, Volcán del Faro, Cova dels Blaus). Fauna composition is clearly dominated by deer, but the faunal remains from rabbits are abundant as well.

“Sites located between the biotopes ... are located at the foot of medium height mountains but not far from flat areas on the sea shore ... The most important example of these is Cova de Parpalló, in Valencia ... Taxonomic composition is mostly made up of goats and deer. Rabbit is very abundant. In sites currently located next to the sea, due to the structure of the sea platform, the sea was not far from the sites during the Upper Pleistocene.” (Villaverde et al. 2012: 8)

Calculating Littoral Landmass

A Geographic Information System reconstruction of the littoral using the General Bathymetric Chart of the Oceans digital map of the world (GEBCO world map, <http://www.gebco.net/>) with a grid resolution of 25-meters by 25-meters suggests that between the Last Glacial Maximum at 18,000 bp and the Magdalenian at 13,000 bp, the littoral of Mediterranean Spain lost 44% of its landmass. This estimate is based data from the northwest continental shelf of Portugal indicating that sea level rose 30 meters to 40 meters (compared to current mean sea level: from -140-meters rose to -100-meters) during the initial phase of deglaciation from 16,000 bp to 13,000 bp (Vaikmäe et al. 2001: 183) in lieu of data from the Red Sea and Eastern Mediterranean showing a 2-centimeter-year⁻¹ rate of sea level rise (Siddall et al. 2003: 855; Galili and Nir 1993: 269). There are two reasons for selecting more moderate data from the Atlantic Coast of Portugal over more assertive data from the Eastern Mediterranean:

1. The rate of Mediterranean shoreline displacement is a function of surface water from the Atlantic Ocean input into the Mediterranean Sea (Zazo et al. 1994).

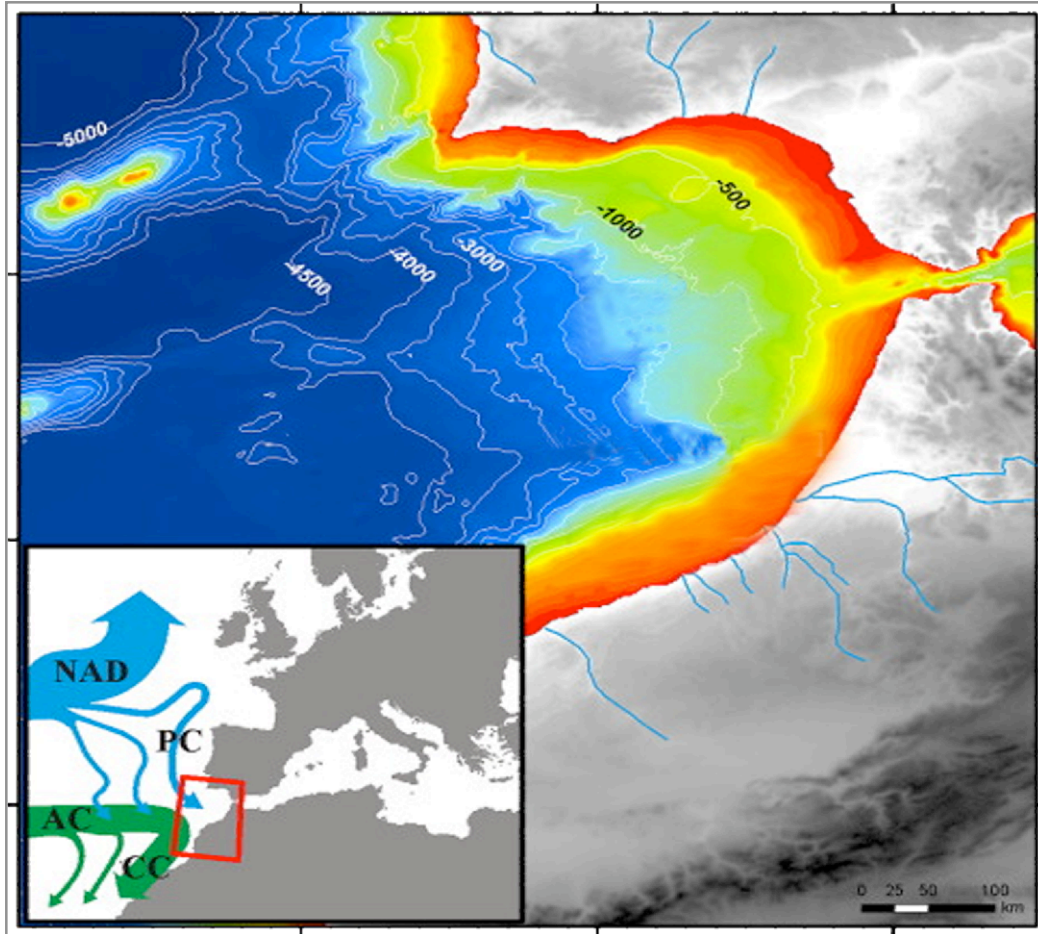


Figure 6. Atlantic Ocean currents controlling Mediterranean Sea level through the Strait of Gibraltar.

North Atlantic Drift (NAD) established circa 13,400 bp.
Portugal Current (PC) is the southern extent of the NAD.

(After Penaud et al. 2010: 1924, Figure 1)

2. The Portugal Current (PC), the southern subset of the North Atlantic Drift (NAD) carries surface water from the Northwest Atlantic Coast of Portugal directly into the Mediterranean Sea through the Strait of Gibraltar (Figure 6). The NAD was established circa 13,400 bp (Penaud et al 2010), putting it in place to carry the freshwater pulse from the Baltic Ice Lake

breech at 12,500 bp (University of Gothenburg 2010; Bergsten and Nordberg 1992) into the Mediterranean Sea.

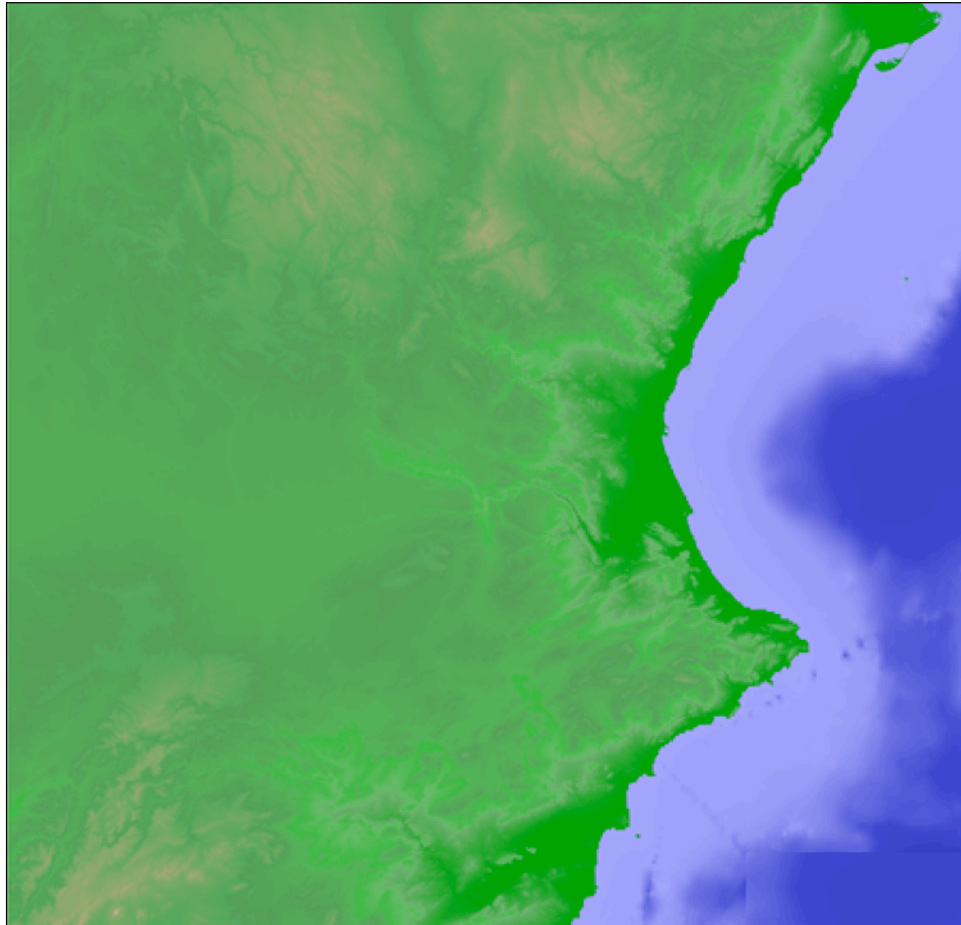


Figure 7. Holocene coastline of La Marina Alta, the central area of Mediterranean Spain at Capo de la Nao.
Shoreline = Current mean sea level

The littoral landmass is calculated by determining LGM landmass and subtracting current shoreline landmass at values. GIS mapping of marine transgression and resulting changes in the surface area (km^2) of the Mediterranean littoral is determined using the following equation:



Figure 8. Holocene coastline of La Marina Alta, the central area of Mediterranean Spain at Capo de la Nao.
 Gray area = elevations above sea level = elevations ≥ 1
 White area = elevations below sea level = null value.

- LGM littoral = current mean sea level + 110 meter

To approximate the LGM shoreline, and effectively lower sea level 110 meters, the elevation value for each raster cell in the digital model is raised 110 meters. (Figures 7 and 9)

- LGM raster cells < 1 = null value
- In the map calculator, all raster cells with an elevation value less than one (below sea level) are converted to a null value and removed from the equation. (Figures 8 and 10)
- LGM raster cells $\geq 1 = 1$

In the map calculator, all raster cells with an elevation value equal to or greater than one, (above sea level) are converted to a value of one.

Sum of all raster cells = the total count of all raster cells.

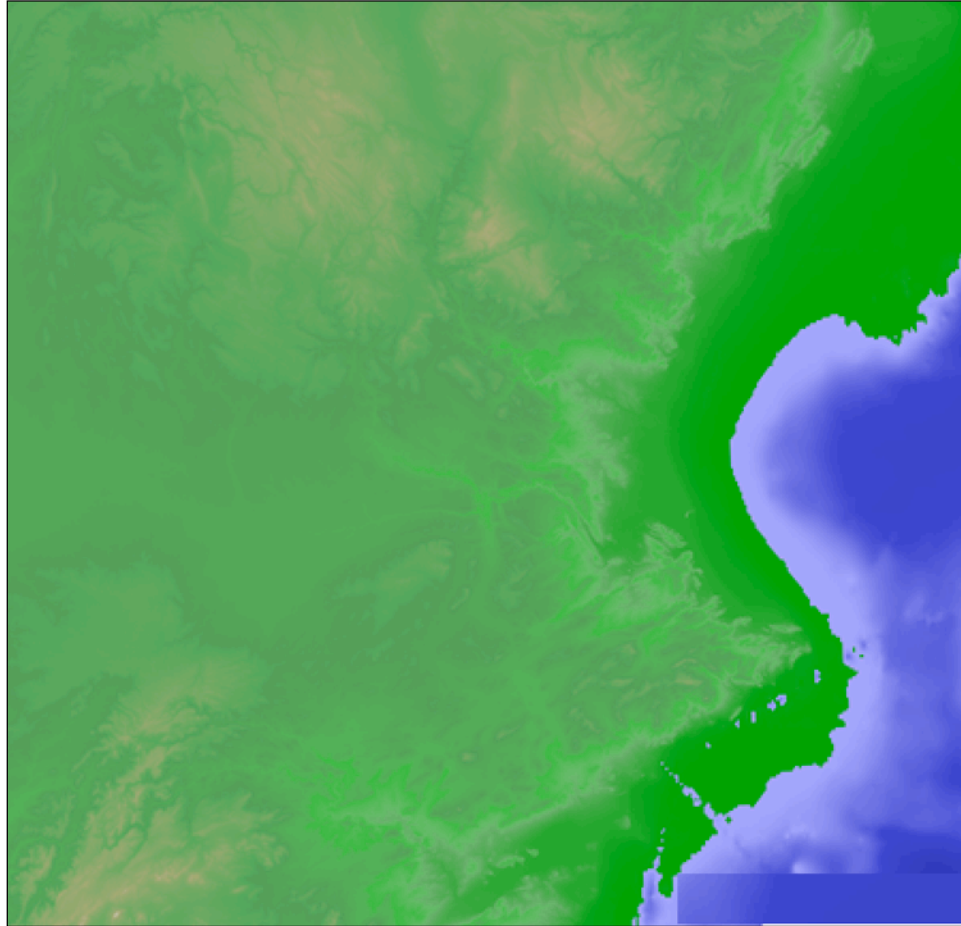


Figure 9. LGM coastline of La Marina Alta, the central area of Mediterranean Spain at Capo de la Nao.
Shoreline = raster cell elevations + 110 meters.
Seal level now = -110 meters.

- Each raster cell = 25m x 25m

$$\text{Each raster cell} = 625 \text{ m}^2$$

- Total land mass $\text{m}^2 = \text{sum raster cells} \times 625 \text{ m}^2$
- Total land mass $\text{km}^2 = \text{total land mass } \text{m}^2 / (1 \times 10^6)$
- $\text{LGM km}^2 - \text{Current mean sea level km}^2 = \text{LGM littoral km}^2$
- $\text{Magdalenian km}^2 - \text{Current mean sea level km}^2 =$
- Magdalenian littoral km^2 (circa 13,000 bp at -70 meters sea level)

- -70 meters sea level = -110 meters sea level (LGM value) +
- 40 meters sea level rise (Vaikmäe et al. 2001: 183).
- Early Holocene km²– Current mean sea level km² =
- Early Holocene littoral km² (circa 9,000 bp at -40 meters sea level)

Rate of sea level rise on the northwest Portuguese coast increased as the Magdalenian progressed, trending upward to -40 meters sea level between 13,000 bp and 11,000 bp, at the terminus of the Pleistocene-Holocene transition (Vaikmäe et al. 2001: 183).

Mediterranean sea level remains relatively stable at -40 meters sea level remains stable until about 9000 bp (Shackleton and van Andel 1985; Shackleton et al. 1984).



Figure 10. LGM Coastline of La Marina Alta, the central area of Mediterranean Spain at Capo de la Nao.
Gray area = elevations above sea level = elevations ≥ 1
White area = elevations below sea level = null value.

Paleoenvironmental reconstructions and analogical evidence suggests the 44% of littoral landmass lost by 13,000 bp included the most productive habitat in terms of the region's largest herbivores, aurochs and horse. After inundation – or importantly, after the effects of inundation like saltwater intruding into groundwater tables and freshwater aquifers of the coastal littoral, as demonstrated at the Llobregat Delta southwest of Barcelona (Manzano et al. 2001) early in the Pleistocene-Holocene transition and at the well of Atlit-Yam in the Eastern Mediterranean in the early Holocene (Galili and Nir 1993; Galili et al. 1993) – the most proximate habitat likely to have herds of large ungulates would have been the southeastern edge Spain's horse and cattle country of today, the relatively open landscape of the Meseta. However, the Meseta in the Upper Paleolithic is generally viewed as inhospitable, resource-poor, and sparsely inhabited, when judged against favored coastal and near-coastal regions (Bicho et al. 2007: 85).

Littoral Landmass Loss and the Meseta

It is reasonable to assume that ungulate herds of *Equus* and *Bos* on the coastal littoral would have left when conditions there became unfavorable. The southeastern Meseta is the nearest habitat for such herd animals adapted to more open plains environments. If herds from the Mediterranean littoral did end up on the Meseta, they would have been in addition to herds already population the region – and they would have increased the draw on hunter-gatherers who once exploited the coastal littoral to shift at least part of their attention to the Meseta, but the extent to which this would have true remains open to question.

“(T)he high, climatically rigorous, generally more barren and resource-poor interior of the Iberian Peninsula was apparently little used by humans during the LGM ... although some forays may have been made onto the Meseta or especially along the major river valleys, such as that of the Tagus (Davidson 1986). Relative to the interior, the coastal zones of the peninsula were attractive to humans in terms of both shelter and food resources.” (Straus 1991b: 267)

Shackleton and van Andel (1985; Shackleton et al. 1984) deal directly with changing coastlines and the loss of coastal littorals in the Mediterranean Basin. Their work emphasizes that it is not enough to think of sea level changes only in terms of landmass lost. The nature of the landmass as subsistence prey habitat must also be considered (Shackleton and van Andel 1985: 8; Shackleton et al. 1984: 308). The LGM Western Mediterranean had coastal plains measuring 60 kilometers wide (Shackleton and van Andel 1985: 10; Shackleton et al. 1984: 310). Similar plains are no longer well represented in the environment of the Mediterranean (Shackleton and van Andel 1985: 12-13):

“(T)he rapid elimination of (coastal littoral) resources during the subsequent fast rise of the sea should have influenced late Paleolithic and Mesolithic hunter-gatherer populations to a degree which deserves more attention from archaeologists than it has thus far received ...

“Just a few millennia of rising sea sufficed to alter this paleogeographic picture drastically. By 10,000 BP the broad coastal plains were mostly gone.” (Shackleton and van Andel 1985: 13-14).

The question remains whether the Meseta region was so inhospitable and otherwise resource poor, as noted above, that it failed to attract Late Upper Paleolithic hunter-gatherers even with the addition of large subsistence prey (*Bos*

primigenius and *Equus* sp.) from the diminishing littoral plain. Relative to coastal and near-coastal regions, the Meseta has few Upper Paleolithic sites, especially before the Magdalenian. Identifiable lithic technologies associated with Upper Paleolithic hunter-gatherers tend to be distributed in coastal regions and outside the interior plateau, but cave art associated with the Upper Paleolithic is found on the Meseta (Davidson 1989: 53). Consideration of the Meseta's potential archaeological record is increasing, though somewhat begrudgingly:

“(D)espite long knowledge of a few classic sites on the mesetas of northern and central Spain (of which researchers often ‘didn't know what to make’ ...) new discoveries and major recent publications have highlighted what a still-limited number of occupation sites indicate ... that although often inhospitable, the interior was inhabited at certain times (notably in the late Magdalenian) by Upper Paleolithic people.” (Bicho et al. 2007: 140)

Doubts about human persistence, if not habitation, on the Meseta extends back in the research annals of Iberia and has the weight of tradition behind it:

“(T)he lack of Upper Palaeolithic industries on the Meseta is well known, and could be explained by failure of Man and animals to exploit the area in a way which conferred any advantage. Any occupation would have been sporadic and have a poor chance of survival in the archaeological record.” (Davidson 1976: 173)

The actual reason for the ephemeral evidence of human use of the Meseta may have to do with the nature of the record and the research methodology employed to explore that record. For example, the Manzanares Valley of the central Meseta, about 200 kilometers west of Albacete, may well have had a high

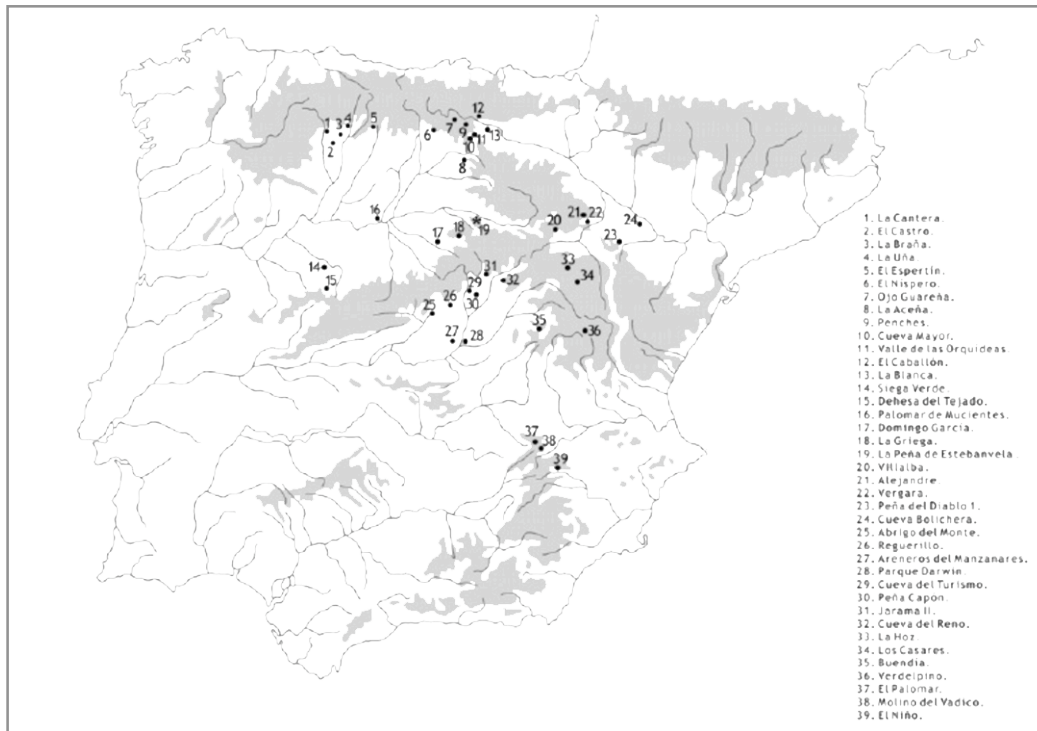


Figure 11. Upper Paleolithic and Epipaleolithic sites on the Meseta, Spain's interior. (Cacho et al. 2010: 116, Figure 1)

concentration of Solutrean sites, unfortunately they were surveyed and excavated in the 1920s without thought given to context (Cacho et al. 2010: 117). The potentially Solutrean material from the Manzanares Valley has since been dispersed to different museums as unprovenanced individual finds (Cacho et al. 2010: 117). As is the case in other regions of the Iberian Peninsula, evidence for human settlement on the Meseta becomes more frequent in the Magdalenian (Cacho 1999), a trend that generally continues through the Early Holocene. The initial phase of the Magdalenian is well documented at La Peña de Estebanvela (Ayllon, Segovia), where zooarchaeological studies suggest that human occupation took place during late summer, autumn, and the transition to winter (Cacho et al 2010: 120). The studies suggest that the Estebanvela's attraction was

its access to a variety of hunting habitats in the vicinity (Figure 12). Given that the seasons of occupation indicate late autumn hunting at Estebanvela may have focused on preparation for winter, it is interesting to note that the faunal assemblage also shows no signs that bones were processed for bone grease (Cacho 2010: 121-122).

The argument remains that particular geographical and climatic conditions on the Meseta have been the main cause of the lack of archaeological evidence attributed to the Upper Paleolithic in comparison with other regions enjoyed more benign conditions (Delibes de Castro and Díez Martín 2006: 13-14). The noted increase of human use of the Meseta in the Magdalenian, after the Bølling

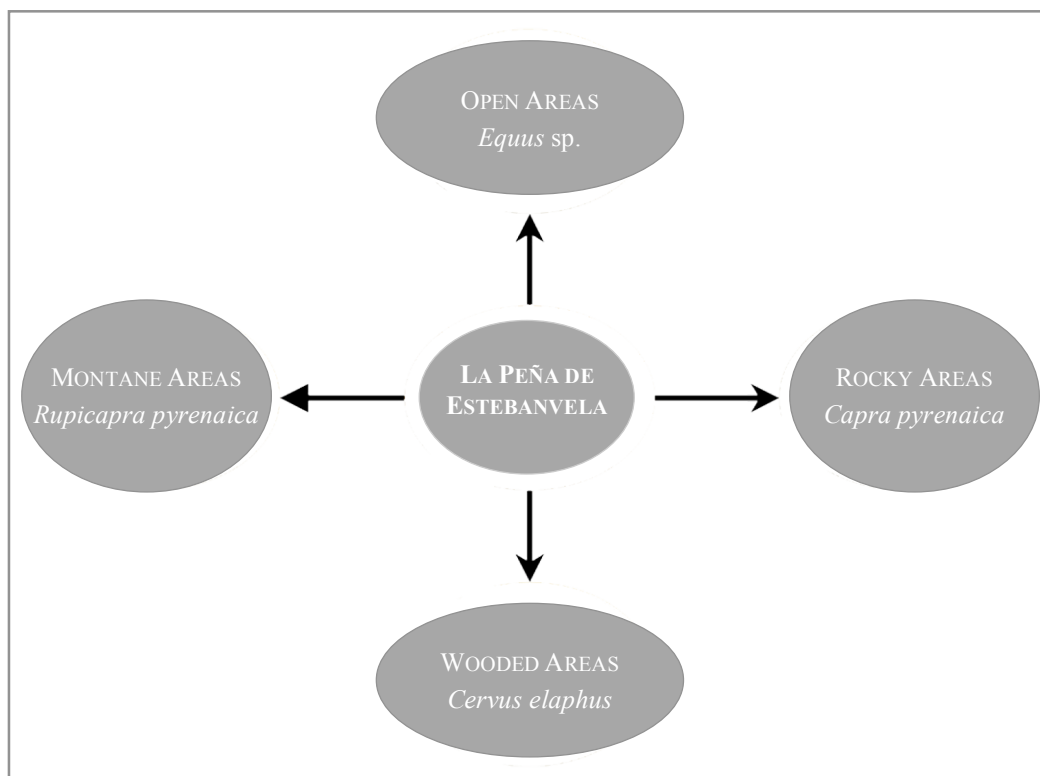


Figure 12. Hunting habitats exploited by Magdalenian hunter-gatherers at La Peña de Estebanvela.
(After Cacho et al. 2012: 49, Figure 5)

interstadial warming at about 14,500 bp, is common to other regions in continental Europe and not specific to the Meseta (Delibes de Castro and Diez Martín 2006). However, it is still not possible to confirm the existence of human groups established on the Meseta in a more or less permanent residency. Excavated caves and rock shelters in the region tend to have limited deposits, often limited comprised of a single archaeological layer (Delibes de Castro and Diez Martín 2006: 14).

What does seem specific to the Meseta and consistent through its history of research is the difficulty archaeologists have had associating the lithic record of the Meseta with Upper Paleolithic techniques and technologies recognized elsewhere on the Iberian Peninsula, particularly on the more densely occupied coastlines. The lithic record appears almost archaic, which may be an indication of that lithic discards on the Meseta resulted from expedient use. For example, the lithic assemblage at El Palacio near Valladolid was originally attributed to the Châtelperronian, however now researchers are inclined to place it, at least generically, within the Late Glacial (Delibes de Castro and Diez Martín 2006: 19). This apparent lithic pattern of expedient use and frequent discard may help to confirm the idea that Upper Paleolithic hunter-gatherers exploited Meseta resources in logistical forays of short duration such that most curated (retouched) lithics carried in were also carried (Kuhn 1994; Riel-Salvatore and Barton 2004; Barton et al. 2011).

In contrast to the Meseta's ephemeral lithic assemblages, the relative abundance of rock art manifestations in both caves and open air locations must

also be considered as testimony to a human presence on the Meseta during the Upper Paleolithic and the Pleistocene-Holocene transition (Delibes de Castro and Diez Martín 2006: 22).

The nature of the human presence is still a subject for future research, since “in the absence of regional research programs, there are still important areas that appear empty of sites” (Delibes de Castro and Diez Martín 2006: 22 – translation from Spanish original Schmich 2013). The relative absence of Meseta research is also noted by Cacho:

“Possibly (the) information gap is due more to the limitations of research since, until recently, the Upper Paleolithic of the peninsula interior has suffered from the disinterest of the Castilian universities and, indeed, of the regional administrations.” (Cacho et al. 2007: 133 – translation from Spanish original Schmich 2012)

The situation is even more pronounced on the southern Meseta, where the density of sites is low and few systematic studies exist (Cacho et al. 2007: 133; Cacho et al. 2012: 44). However, the difficulty of associating ephemeral, expedient lithic assemblages (scatters in most cases) on the Northern Meseta with Upper Paleolithic technology known from coastal areas of Cantabria and the Mediterranean suggested above by Delibes de Castro and Diez Martín (2006: 19) has also been noted on the southern Meseta near Cueva del Niño, south of the city of Albacete.

“A picture ... emerges of a sub-continental Iberia with a dry cold core of high plains, surrounded by an enlarged coastal region. The harsh climate of the core, and its isolation by warmer regions around it ... would explain the effective absence of Upper Palaeolithic sites in the core, and the gradual extension into the edges of the core in the later periods.”
(Davidson 1986: 110)

In trying to account for the frequent surface scatters of local quartzite flakes observed in surveys conducted as part of the El Niño excavations, Davidson proposes three possible hypotheses:

- “1. The industries exist, but lack of research means that they have not been found, or have been obscured by geomorphological changes or other post-depositional changes.
2. The industries do not exist. The inland areas were abandoned during the cold periods.
3. The industries exist and have been found, but we do not yet have any means of recognizing them as the products of makers of Upper Palaeolithic industries.

“The first possibility seems unlikely, as no evidence for Upper Palaeolithic industries was found in a survey carried out in Albacete province during my excavation at the Cueva del Niño.”

(Davidson 1986: 111)

“The second hypothesis means that we must postulate that the Upper Palaeolithic art (on the Meseta) was produced in apparently mad dashes from the security of warmer climates. If the art were confined to one site, or if it were confined to one region, it would be possible to account for it by such serendipitous accident, but there are several sites, and they are distributed rather far into the inland, both in the northern *Meseta* and in the southern. I prefer not to accept the second hypothesis, and look forward to its future falsification.” (Davidson 1986: 111-112)

“The third hypothesis is the most intriguing. The evidence from Niño suggests that the opportunistic flaking of quartzite pebbles continued throughout the sequence there. ... Straus (1980) has shown at La Riera, in Asturias province, that quartzite was more often used than flint for ‘archaic’ tool-types. Flint was used preferentially for Upper Palaeolithic tool-types ... It is not unreasonable to suppose that some of the quartzite industries collected during the survey in Albacete were of Upper Palaeolithic or later date, although current methods of analysis do not allow us to recognize them as such.” (Davidson 1986: 112)

“If summer daytime activities involved the dispersal of small groups of collectors over wide areas, in an area with abundant stone raw material available on the surface one might predict the production of ‘expedient’ tools, resulting in the presence over much of the landscape of small scatters of flaked stone of ‘archaic’ type.” (Davidson 1986: 112).

“This may simply reflect the raw material available there, or ... it may also be the result of a set of activities by people who otherwise are recognized by their discard of ‘Upper Palaeolithic’ tools in lowland caves. Such activities may have involved the seasonal exploitation of ephemeral plants, rapid-breeding animals, or animals which were seasonally migratory.” (Davidson 1986: 112).

“A curious paradox emerges, that the region of the Peninsula ... characterized as the cold core contains many open-air sites, while the majority of the cave sites are in the warmer regions bordering the cold

core. The opposite situation might have been expected. ... The greater abundance of open sites in the cold core, relative to the coastal region, may be partly a result of the different geomorphological history of the two regions, with a tendency for sites in the hinterland to be revealed by erosion and sites in the coastal lowlands to be concealed by deposition. But it is also partly a result of the different patterns of dispersion of activities in the two regions.” (Davidson 1986: 112).

Future research needs to view the limits imposed by climatic conditions as a possible hypothesis rather than a proven conclusion (Delibes de Castro and Diez Martín 2006: 22). Going forward, research programs should emphasize systematic surveys and excavations developed with a multidisciplinary approach and designed to expand the archaeological record, occupancy profiling models, and our understanding of mobility and territoriality on the Meseta (Cacho et al. 2007: 133 – translation from Spanish original Schmich 2012).

While the majority of currently identified sites are located in caves and rock shelters with open air sites noticeably scarce on the Meseta, it is not clear whether the lack of open air sites reflects a “characteristic pattern of occupation ... or whether, as seems more logical, this shortage is mainly related to the limitations of field research” (Delibes de Castro and Diez Martín 2006: 22 – translation from Spanish original Schmich 2013).

“It does not seem, therefore, that climate has been a factor in the colonization of these interiors lands, especially when you consider the

resilience of human groups living in other European regions (Central European), where environmental conditions were more extreme.” (Cacho et al. 2007: 133 – translation from Spanish original Schmich 2012)

The Post Glacial re-colonization of newly accessible landscapes in Switzerland is a case in point (Leesch et al. 2012). As is true on the Spanish Meseta, Paleolithic research in Switzerland focuses on caves and rock shelters, probably because they are more visible to archaeologists. As is also true in Spain (and as noted above) there is a feeling in Switzerland that the distribution of the more than 50 Magdalenian sites currently recorded may be attributable to research protocols and may not be an accurate reflection of habitation patterns on the landscape (Leesch et al. 2012). Counter-intuitively, Magdalenian re-colonization of Switzerland began in the cold, treeless environment of the Oldest Dryas – in the newly ice-free region less than 50 kilometers north of the remaining glaciers – and was not a function of the Greenland Interstadial 1e warming period (Leesch et al. 2012). Moreover, the distribution of open air sites indicates that such camps were commonly used along with caves and rock shelters. The largest Magdalenian open camp was on the intensively occupied, cave-free Swiss Plateau (Leesch et al. 2012: 195). The evidence suggests “Switzerland was colonized independently from temperature but in relation with the development of the vegetation cover and the density of horse and reindeer populations” (Leesch et al. 2012: 191).

Assuming that archaeological lessons from the Swiss Plateau are applicable to the Iberian interior plateau, Magdalenian hunter-gatherers exploiting the Meseta, were more concerned with potentially available resources than inhospitable cold.

Littoral as Productive Habitat

The effectiveness of the Mediterranean littoral as a subsistence resource is a function of two attributes:

Period	Littoral (km²)	Lost (km²)	% Lost
LGM (18,000 bp)	12,047		
Magdalenian (13,000 bp)	6,759	5,288	44%
Early Holocene (11,000 - 9,000 bp)	3,101	8,946	74%

Table 3. Shoreline displacement in Mediterranean Spain.
Based on estimates in Figure 4.
Littoral = (LGM landmass) – (Current landmass)
Lost = (LGM littoral) – (Magdalenian littoral)
(Magdalenian littoral) – (Early Holocene littoral)
Littoral estimates in square kilometers.

1. Landmass (Table 3)

Ability to serve as a range for sufficient subsistence prey

Resilience to disturbances while retaining subsistence value

2. Vegetation

Attractiveness the kinds of large herbivores that figured

prominently in optimal foraging decisions by

hunter-gatherers during the PH-t.

Maintenance of open grassland and scrub communities

conducive to larger herds of herbivores.

Villaverde estimated the Mediterranean littoral at 30-50 kilometers wide near its mid-point at Capo de la Nao (Villaverde Bonilla et al. 2012: 8). Aura was more conservative, noting that “the marine transgression had uneven consequences ... depending on local lithology, coastal bathymetry and morphology” (Aura et al. 1998: 97). Aura put the Pleniglacial littoral along the Gulf of Valencia at 10-20 km wide, while farther south on the coast of eastern

Andalucia the littoral may have been no more than five kilometers wide in places.

This inequality in littoral extent – four times as wide north of Cabo de la Nao (the regional mid-point) as south of Cabo de la Nao – ultimately appears to be pivotal in the north to south retention of littoral habitat and subsistence prey species during the Pleistocene-Holocene transition. There was greater initial mass north of Capo de la Nao to the structure of the coastal shelf that became the littoral at the LGM. This translated into a generally wider littoral north of the regional mid-point that retained a presence of aurochs (*Bos primigenius*) and horse (*Equus* sp.), the largest sources of protein and fat on the landscape, longer into the early Holocene.

Assuming the efficacy of the estimates in Figure 4 and Table 3, the King Ranch of Texas, one of the largest ranches in North America, is a useful analogous comparative. The King Ranch encompasses 3,340 kilometers² of coastal littoral along the Gulf of Mexico from Corpus Christi, Texas to Brownsville, Texas. Its habitat includes open live oak *mottes* (a Texas term for small stands of trees on a prairie), mixed brush environments, extensive coastal prairies, and marshes (Fitzpatrick 2012; Forgason and Fulbright 2003). Although it is difficult to obtain an accurate count of domesticated *Bos* sp. on a working ranch, the King Ranch maintains water sources for 85,000 head of Santa Gertrudis breed – a cross between *Bos indicus* and *Bos taurus*) at any one time. The ranch also has a herd of 3000 horses (*Equus caballus*).

In addition, like many ranches in Texas, to make the economics work, the King Ranch sells hunts-for-a-fee (only ~2% of the land in Texas is public access).

King Ranch hunting seasons last three to six months annually (depending on the species) for deer, wild turkey, javelina, wild hog, and nilgai (*Boselaphus tragocamelus*) a large antelope (120 to 240 kilograms) originally from India. The number of hunters varies each year, but the number is qualitatively said to be in the hundreds of hunters annually (Baen 1997; McCoy et al. 2005).

Resource Base Potential

The human hunter-gatherers of Mediterranean Spain lost a potential resource base and foraging habitat almost twice the magnitude of the King Ranch as the Mediterranean Sea inundated the coastal littoral at 13,000 bp during the Magdalenian of the Late Pleistocene.

The nearest Mediterranean coastal landscape cognate comes from Biological Reserve of Doñana National Park and the at the delta mouth of the Guadalquivir River on the Atlantic Ocean near Huelva, about 125 kilometers up the southwest coast of Spain from Gibraltar (Finlayson et al. 2008; see also Rogers and Meyers 1980 for a landscape description and classification). The Reserve's environment is based on a thermo-Mediterranean climate typical of the coastal plains that existed in the region for much of the late Pleistocene from the Last Glacial Maximum to the point of saltwater inundation.

The Mediterranean littoral of the Pleistocene Holocene Transition (PH-t) is modeled on the Biological Reserve of Doñana National Park at Huelva, on the southern Atlantic Coast of Spain about 125 kilometers northwest of Gibraltar (Carrión et al. 2008; Finlayson et al. 2008a) based the following criteria:

- Environmental reconstruction based on pollen and charcoal data
- from Gorham's Cave, Gibraltar circa 18,400 bp – 10,900 bp.
- Arboreal pollen component: open parkland mix of coniferous and deciduous woodlands – oak, pine, and juniper.
- Non-arboreal pollen component: open grasslands with heaths, Mediterranean coastal scrub, and heliophytic *matorrales*.

Matorrales are the Mediterranean equivalent of open live oak *mottes* noted above at the King Ranch of Texas.

- Phreatophytic associations: riverine forests and marshy wetlands
- The reconstructed littoral 'reservoir of diversity' extends along to Mediterranean coastal shelf from Gibraltar to Murcia (Carrión et al. 2008; Finlayson et al. 2008a).
- This study extends the littoral reconstruction north to the Pyrenees for this research based on comparable mean monthly temperature and precipitation values: Cartagena, Murcia to Valencia, País Valencia to Barcelona, Catalonia.

Finlayson argued for the Biological Reserve of Doñana National Park being comparable to the Pleistocene littoral near Gorham's Cave largely based on the fact that modern temperature (Figure 13) and precipitation values (Figure 14) fall well within the Pleistocene ranges as estimated from palynology and anthracology analysis (Finlayson et al. 2008a, 2008b, 2006). The Finlayson research team has interpreted excavated assemblages at Gorham's Cave using behavioral observations from the Biological Reserve of Doñana National Park

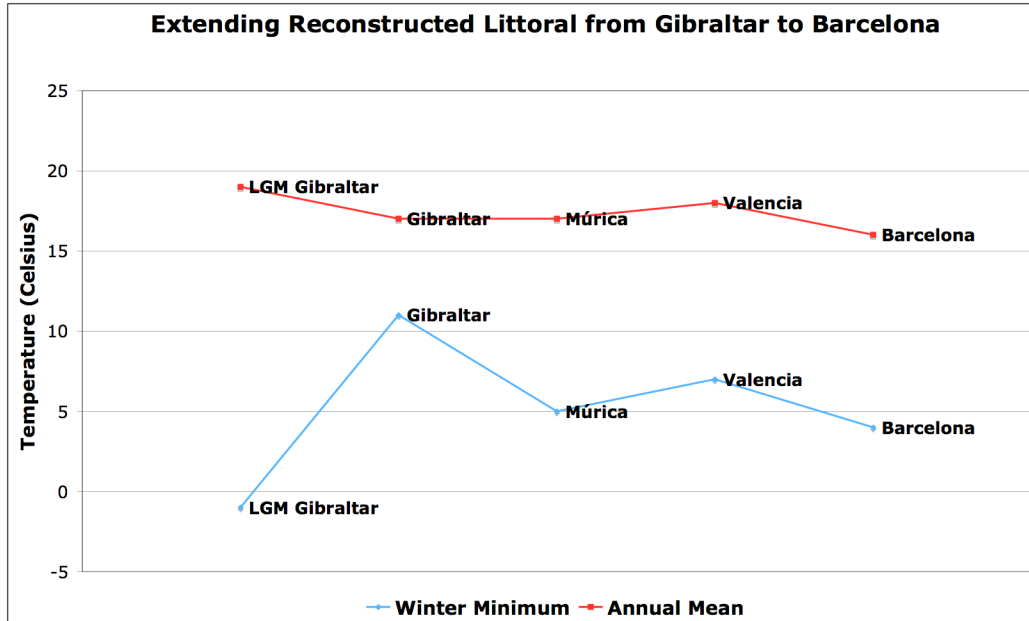


Figure 13. Coldest/Minimum winter temperatures > estimated LGM winter low temperatures for the reconstructed Gorham's Cave littoral at Gibraltar.
Annual mean temperatures fall within LGM values at Gibraltar estimated from pollen and charcoal analysis. (Finlayson et al. 2008a, 2008b; Carrión et al. 2008)
Data from the Norwegian Meteorological Institute (<http://www.yr.no/place/Spain/>)

Carrión extended the reconstructed littoral as far north as Murcia using both analogous modern values in combination with palynological analysis of regional archaeological sites with secure contexts (Carrión et al. 2008).

Since the critical measures of minimum/coldest winter temperature and mean annual temperature (Figure 13), in addition to annual precipitation (Figure 14), for Valencia and Barcelona also fall within the estimated LGM ranges for the littoral reconstruction used at Gorham's Cave – the Biological Reserve of Doñana National Park is considered analogous to the entire Mediterranean littoral during the Pleistocene Holocene transition in this study.

The primary mammalian species in the Biological Reserve at Coto Doñana National Park are:

- Red deer (*Cervus elaphus*)
- Horse (*Equus caballus*)

Feral population of European Retuerta horse

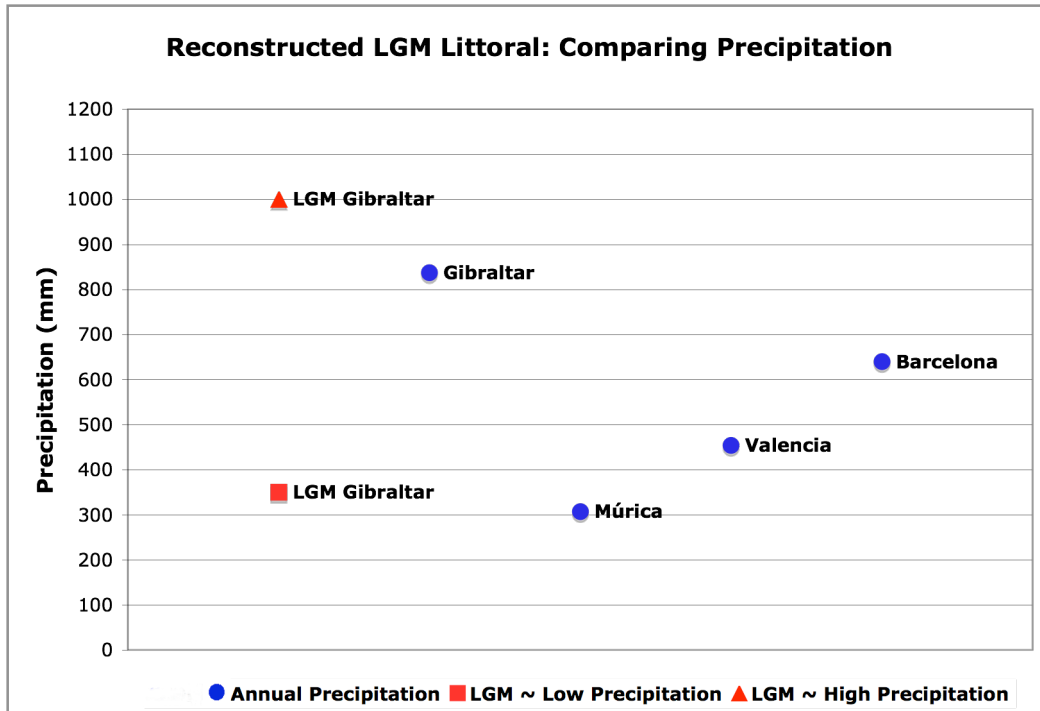


Figure 14. Annual precipitation measures for the Mediterranean Coast fall within the high and low estimated LGM values from Pleistocene research at Gorham's Cave, Gibraltar. (Finlayson et al. 2008a, 2008b; Carrión et al. 2008)

- Cattle (*Bos taurus*)

Feral population of European 'Mostrenca' cattle as a stand-in for movement patterns and habitat preferences of Aurochs (*Bos primigenius*)

- Wild boar (*Sus scrofa*)

The Retuerta horse (an Andalusian breed of *Equus caballus* and one of the most ancient breeds of horse remaining in Europe) roams throughout the Biological Reserve, and is used in studies to “illustrate the possible habits of the horses that have been recorded in the fossil record” (Finlayson et al. 2008: 2149). Horses were are observed mainly in open areas of low grasses and *Euphorbiaceae* mixed grasslands bordering marsh areas, and they were always close to fresh water sources. Horses unaccounted for in studies at the Reserve are thought have remained hidden in the marshes. During flooding episodes, horses congregated on dry ground in grassland areas (Finlayson et al. 2008: 2149).

Mostrenca cattle (*Bos taurus*) at the Biological Reserve of Doñana National Park are also a feral population of an indigenous Iberian breed (Finlayson et al. 2008: 2149). The Mostrenca is a descendant of Andalusian Black cross-bred with herds of fighting herds in Andalusia. It is officially recognized as autochthonous Spanish breed of special protection in the Spanish catalogue of livestock breeds (Vallecillo et al. 2005). The cattle may represent a remnant of a primitive cattle group in Western Europe dating to the 13th century (Alderson 1992; Lazo 1995). While not the same species as Pleistocene aurochs, the cattle at the Biological Reserve are indigenous and have been free ranging for centuries. Their behavior is indicative of *Bos primigenius* (Finlayson et al. 2008: 2149) during the Pleistocene-Holocene transition.

“Cattle ranging behaviour was not affected by human interference, and was shown to be regulated by a complex interaction of environment, individual and social factors. Habitat structure and seasonal fluctuations in abundance and distribution of resources determined general patterns of

ranging behaviour: the greater the concentration of resources, the smaller the home ranges of individuals and social groups. These patterns were modified at an individual level by the sex of the animal and its reproductive status if male. Social influences on ranging behaviour were important because these implied the segregation of home ranges among dominant bulls and among social groups. As a result, there was a great variability in space use and home-range behaviour.” (Lazso 1995: 24)

As stand-ins for aurochs at the Biological Reserve of Doñana National Park, the Mostrenca cattle are not tied to territories. When the bulls move, the herds move. The bulls move when conditions are better elsewhere,. Studies in the 1980s and 1990s found that the Mostrenca were more concentrated in the landscape in the years immediately after increased rainfall, when the grasses were still abundant in response to the higher water table (Finlayson et al. 2008: 2149). From these observational studies, therefore, it appears that if the water table or freshwater aquifer was inundated by saltwater as it was at the Llobregat River Delta aquifer near Barcelona, then it is reasonable to assume the wild cattle (or feral cattle in this case) would move on as soon as the grasses and forbs were affected. It appears this continues to happen in the feral herds of both cattle and horse in the Biological Reserve of Doñana National Park.

Like the Llobregat River Delta, the Doñana aquifer system of southwestern Spain also was inundated by rising sea levels during the Pleistocene-Holocene transition (Manzano et al. 2001: 116-123). About half of the confined Pleistocene aquifer has been freshened by late Holocene precipitation regimes and groundwater input (Manzano et al. 2001: 123). This

freshened groundwater flowing to the southeast has discharged as upward flow in the marshland areas for about the last 6000 years (Manzano et al. 2001: 123). Until the 21st century, before greater demands from surrounding agricultural areas and human inhabitants, it was still visible in flowing wells (Manzano et al. 2001: 123). The most affected portions of the aquifer and the grasslands above them were under saltwater – these are now elements of the Atlantic Ocean and its coastline. At the Last Glacial Maximum, the low point of global sea levels leading into the Pleistocene-Holocene transition, aquifers and water tables were essentially free to flow farther outward on the coastal littoral, including that part of the littoral that now forms the undersea shelf off the coast of Spain.

Studies at the Biological Reserve in Doñana National Park are based on:

- 21 one-hectare study plots at 0.5 km intervals integrated with Iberian survey sampling 980 plots.
- 300 km² (30,000 hectares) ‘virtually untouched habitats’ strictly protected in reserve.
- Data recorded monthly at each Biological Reserve plot over three-year study: bird survey and census, mammal survey and census, vegetation survey.
- Three geological zones: ancient depression (tectonic) silted with deltaic deposits from river, large coastal plain, and sand barrier.
- Dominant habitat is an open woodland ‘savannah’ with patches of denser woodland and thickets.

- Bioclimatically comparable to coastal plain within the period ca. 18.4 ka BP to ca. 10.9 ka BP
- “As a result of the high level of protection ... we consider that the area of the Doñana National Park, and more specifically the Biological Reserve, is one of the few remaining zones within Iberia that can be used as a proxy for the habitats and landscapes that were located in the zone of the emerged shelf that existed ... for much of the late Pleistocene.”

(Finlayson et al. 2008: 2146)

It is reasonable, therefore, to extrapolate and apply landscape descriptions of the current Biological Reserve in Doñana National Park to the coastal littoral of La Marina Alta on the Mediterranean Sea up to the point of their inundation:

“The ‘dry’ areas can be divided into two basic kinds of habitat: shifting sands (rows of dunes running from the beach towards the ‘marisma’) and the stabilized sands, covered in where ‘maquis’ or scrub (‘monte blanco’ in the drier areas and ‘monte negro’ where the groundwater is closer to the surface), a home for large cork oaks. The buffer zone between the ‘marisma’ and the sands, called ‘vera,’ is the richest, as it is kept fairly wet throughout the year by the groundwater. This is where most of the park’s land vertebrates live.”

(Aymerich 1992: 33)

The vera is the ecotone described as the main habitat for feral cattle and horses at Doñana National Park – for example “Horses were observed mostly in La Vera and the lakes, always close to fresh water sources” (Finlayson et al. 2008: 2149). But the aquifer still contains old saline water from sea level rise during the

Terminal Pleistocene (Manzano et al. 2001: 123), and consequently the aquifer in Doñana National Park is something of a two-edged sword:

“In addition, there are some places, near the river, a bit deeper, which stay flooded for large periods; they become into lagoons, with a high salinity, which stops the growth of vegetation. When these lagoons get dried, a white salt bed is sediment over the clay; these zones are known in the region as lucios, being the biggest Lucio del Membrillo.

“The limit of the clays is constituted by the vera, which is a transition zone or ecotone, between the marsh and the dunes and cotos. This narrow band is the discharge zone of groundwaters filtered through the sands of the cotos and dunes, improving the growth of rush and pasture...” (Montero and González 2004: 18-19).

“In the semiconfined aquifer the total mineralisation as well as the sodium chloride character increases towards the deepest aquifer zones, where there are saline waters of a marine origin. These marine waters were originated during the process of filling of the estuary, where they remained occluded in the geological formations; later, due to the push of the recharging waters proceeding from the unconfined aquifer, the salty water was displaced towards the south giving place to the coexistence of two different quality zones.” (Montero and González 2004: 23)

From 22,000 to 15,000 years ago, the islands of the Dalmatian coast were elongated hills overlooking a large, well-watered plain that could have held large animal herds (Shackleton and van Andel 1985: 15). Accepting the possibility that plain may have been the largest and best food resource in the region, makes the islands prime candidates for late Paleolithic base camp sites, rather than merely having to be considered as potential locations for littoral extraction camps in a coast-to-mountain cycle. Though any open-air, plains hunting camps plain would

now be under the Adriatic Sea, the base camp sites on the slopes of the present Dalmatian islands may still be accessible (Shackleton and van Andel 1985: 15).

“Any consideration of hunter-gatherer activity in terms of size of territory, or any distinction between home base and specialized sites such as extraction camps must rely on an accurate and detailed perception of available resources... (O)ptions were often present in the past which were radically different from those that could be inferred from the present geography. Conversely, a clear understanding of the ancient landscape at low sea level might well provide fresh leads to areas of potential archaeological interest not obvious to contemplation of only the present environmental setting.” (Shackleton and van Andel 1985: 15)

The exact timing of coastal shelf habitat loss in Mediterranean Spain may never be known. Catalonia, Valencia and the Balearic Islands have established regulations protecting coastal marine seagrasses, including *Posidonia oceanica*, *Cymodocea nodosa* and *Zostera noltii* (Oceana 2012: 15). This precludes most extensive underwater research that involve dredging or coring.

Observational studies in the Biological Reserve at Doñana National Park indicate the lost littoral area would have been favorable habitat for open-area adapted species of ungulate herds of *Bos* (aurochs) and *Equus* (horse). The same studies also show that salinity in the water table and aquifers affects the vegetation available to these herbivores and, therefore, their distribution on the landscape. When the lead males in *Bos* and *Equus* herds decide it is advantageous to move, then the entire herd moves. In the case of Mediterranean Spain and the coastal littoral, the nearest open-area habitat for *Bos* and *Equus* herds would have been the southeastern edge of the Meseta.

CHAPTER 5

THE FAUNAL RECORD

Species redistribution due to environmental transformation during the Pleistocene-Holocene transition would have brought about a corresponding change in the movement patterns of hunter-gatherers in Mediterranean Spain. However, the nature of such a species redistribution and its ripple effects are not apparent in the sites far enough away from the Pleistocene littoral to have survived the full extent of sea level rise. Therefore, the nature and effects a species must be inferred from indirect evidence.

The faunal assemblage at Cova de les Cendres, on the current Mediterranean coast, has *Equus* and *Bos* in Solutrean levels, but there is no evidence of either in the Magdalenian (Villaverde et al. 1998). As sea level rose during the tardiglacial and submerged the littoral – including the area separating Cova de les Cendres and the coast – the plain at the edge of the southern Meseta is the logical range for horse and aurochs redistribution. There is direct evidence of *Equus* remains in Magdalenian contexts on the Meseta (Cacho and Perez 1997), and rock art evidence for both *Equus* and *Bos* on the Meseta during the Upper Paleolithic (Bicho et al. 2007, Cacho and Perez 1997). Although the Meseta is referred to as “high, relatively inhospitable and resource-poor” (Bicho et al. 2007: 85) in the Upper Paleolithic, this is a qualitative statement and a reflection of the fact that we currently lack enough data to make definitive quantified statements about the resource value of the Meseta. This is especially

true as it regards the lack of evidence for Late Pleistocene resource exploitation of the southern Meseta (Cacho et al. 2012).

Even on the Meseta writ large there are marked differences between the remnant faunal assemblages. Red deer (*Cervus elaphus*) predominate at mountain rock shelters in the region of Segovia between Madrid and Burgos, but at Cueva del Búho/Zarzamora bordering the open plains of the same region *Bos* and *Equus* comprise 68% of the faunal assemblage by count of the Minimum Number of Individuals (MNI) (Nohemi Sala et al. 2011: 75). The radiocarbon dating sequence at Cueva de Búho remains tentative, but microfaunal associations place the site near the beginning of the Last Glacial Maximum.

The association of *Bos* and *Equus* with open plateau landscapes dotted by oak parkland is strong enough that researchers who do work on the Meseta use their presence to reconstruct late Pleistocene environments (Cacho et al. 20102; Nohemi Sala et al. 2011). The association has been confirmed by pollen analysis in specific study areas (Nohemi Sala et al. 2011: 80)

At La Peña de Estebanvela in Segovia, a number of marine gastropod shells made into objects of personal ornaments present clear evidence that Magdalenian groups in the interior of Spain maintained contact with the Mediterranean region (Cacho et al. 2012). The shell ornaments from La Peña de Estebanvela suggest either back-and-forth movement between the Segovia Meseta and the Mediterranean coast or exchange networks that bridged the distance between the Mediterranean Sea and the northwest Meseta (Cacho et al. 2012).

The open Meseta region is cattle and horse country in Iberia today. Given the wide-ranging adaptability of aurochs and horse (cf. Sommer et al. 2011) within relatively open landscapes, we can assume it was also cattle and horse country at the Pleistocene-Holocene transition.

There is also a social component to procuring relatively large subsistence prey such as *Bos* and *Equus* (see Table 4 for sizes of Late Pleistocene subsistence prey). As demonstrated by proto-historic and historic bison hunts on the northern plains of North America, and extrapolated from Paleo-Indian “buffalo jump” sites, hunting such large prey often involved cooperation between groups and certainly within groups. Large herbivores in large herds are able to support the aggregation episodes of aggregation and dispersal strategies for maintaining marriage networks and risk mitigating alliances.

Communal Hunting

Archaeologists in North America view Paleo-Indian communal hunts of *Bison antiquus* (and later prehistoric and proto-historic hunts of *Bison bison*) as opportunities for social aggregation (Bamforth 1991; Hoffman 1994; Hill 2007: 285-288). The implied relationship between communal hunts large animals that gather in large herds and social aggregation of human groups is one of the two-way streets of archaeological thought. Taking full advantage of large animals in large herds requires planning and preparation before the hunt, and a labor force sufficient to process the results of the hunt afterward (Frison 2004: 167-168, 225-227). These requirements are best met by communities of hunters – by a

Species	Live Weight (kgs)	Meat Yield (kgs)	Winter Fat Content (%)	Winter Fat Content (kgs)
<i>Rangifer tarandus</i>	120	66	2%	1.32
<i>Cervus</i>	340	187	2%	3.7
<i>Equus caballus</i>	350	192.5	5%	9.6
<i>Equus hydruntinus</i>	260	143	5%	7.2
Large Bovine (e.g., <i>Bos primigenius</i>)	1400	770	5%	38.5
<i>Capra ibex</i>	40	22	5%	1.1
<i>Rupicapra</i>	35	19	5%	1.0
<i>Sus scrofa</i>	75	41	5%	2.1
<i>Lepus</i>	4.5	2	0%	0.0

Table 4. Prey Species of the Late Pleistocene.
Meat Yield = Live Weight – 55% (*Lepus* = 44%).
Winter Fat Content (kgs) calculated from Meat Yield.
(After Spiess 1979: 214, Table 6.13)

“temporary fusion of individuals from multiple social groups” (Hill 2007: 285; see also Hofman 1994: 286). At the same time, communities of hunters require a sufficient input of resources to sustain them, and this requirement is best met by hunting large animals gathered in large herds. There is also a need for what might be termed support resources: water, firewood, edible plants, and shelter in a protected setting. The convergence of needs points to specific locations where river valleys and other natural corridors where leave the foothills or mountains at the edge of the Meseta. Natural meeting points on the ecotonal edges like the southern edge of the Meseta and the confluence of the Guadiana River basin source and the west to north sweep of the Jucar River basin (near Albacete, Spain and the Magdalenian site of Cueva del Niño – Figure 15) can be readily located and described (communicated) by diverse social groups planning a communal hunt (Hofman 1994; Hill 2007: 286-287). The Cueva del Niño area could have drawn social groups from both the Atlantic Coast and the Mediterranean Coast.

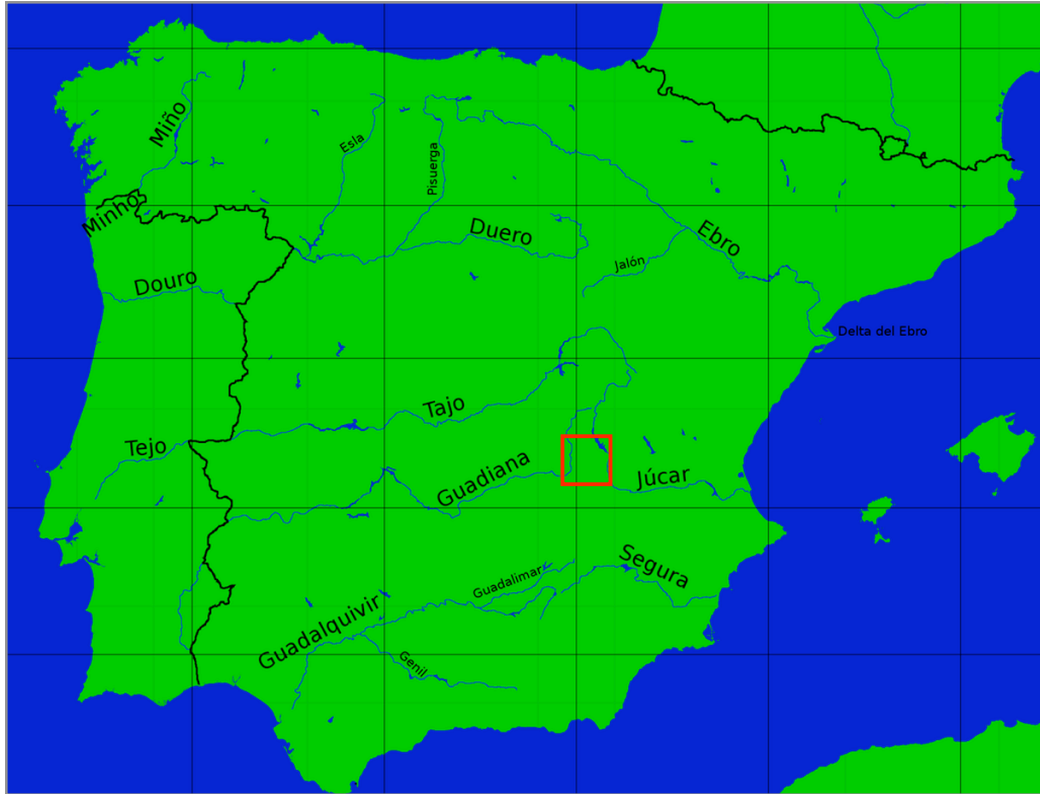


Figure 15. □ Cueva del Niño area located between the Guadiana and Júcar River drainages on the southern reach of the Meseta.

There is a regional association between environmental change after the Last Glacial Maximum and subsistence diversification that appears related to the availability of species and resources (Aura et al. 2009: 4). Other factors such as technological innovation, demography, territoriality, and cultural trajectories could have played a role in the association (Aura et al. 2009: 4). Demography would include population pressure brought about by hunter-gatherers in Mediterranean Spain sorting themselves out as pulses of glacial meltwater influx caused episodes of rapid sea level rise and the increasing loss of habitat. It has been observed that ecological changes “at the end of the Pleistocene could have favoured a redistribution of some mammal species, such as *Bos primigenius*

and *Equus sp.*, whose remains are found less frequently” (Aura et al. 2009: 4) in Mediterranean Spain during the Tardiglacial.

Although *Equus* and *Bos* decreased in frequency throughout the Late Glacial of Mediterranean Spain, they were more abundant in open-area sites such as Peña del Diablo and Vergara (Aura et al. 2011: 353) on the southern edge of the Ebro Basin (González-Sampériz et al. 2005). *Bos* are especially prevalent at the Mendandia rock-shelter in the upper Ebro Basin of the northwestern Meseta, which is a kill site that specialized in *Bos primigenius* (Alday and Cava 2006; Aura et al. 2011: 353).

The existence of open-area kill sites for large ungulate species like *Bos* and *Equus* that congregate in large herds during a breeding season, can be an important factor in the formation process of some faunal assemblages:

“(S)tatistics mask ... the complexities of interpretation of the faunal remains. It is not clear that the bones at an archaeological site (or even at regional groups of them) reflect in any simple way the availability of animals to ... prehistoric people. We have few independent estimates of species abundance to enable us to assess the relationship between species abundance in the environment and prey selections by the hunters (Davidson 1981). It is correspondingly difficult to estimate what proportion of the catch was transported back to the archaeological site or what role any particular site had in the annual or longer cycle of faunal exploitation in the region. In-field butchery may differentially affect the representation of larger species in the faunal record.”
(Davidson 2005/2006: 201)

Field Dressing and Transport

In even the best preservation circumstances, it is difficult to correlate the bones people did not eat with meaningful statements about the meat they did. Jonathan Haws rightly notes “One of the most debated topics in zooarchaeology centers on the bones left behind by prehistoric hunters at kill sites and carried away and discarded at base camps” (Haws 2003: 185). Haws uses Bunn (1991) to trace the origins of the debate to Lartet and Christy (1865-1875), who first suggested that the skeletal part frequencies of the French Paleolithic sites reflected the transport decisions of prehistoric hunters (Haws 2003: 185-188). Ultimately, Haws (2003: 185) notes that “zooarchaeologists have realized there is a great deal of variability in bone assemblages and numerous causes for their composition. There is no ... simple dichotomy between kill sites and residential sites ...” He may also have posited one of the critical junctures in the ongoing debate over bones left behind and bones carried back.

As noted above, Saint-Germain-la-Rivière (Drucker and Henry-Gambier 2005) offers the rare opportunity to compare faunal NISP and MNI data with isotopic analysis of well-preserved human bone collagen from the same Magdalenian. At Saint-Germain-la-Rivière, human diet correlated most closely with estimated ratios of meat yield (species MNI x mean weight in kilograms) and was not related to either NISP or MNI data alone. Moreover, human diet at Saint-Germain-la-Rivière showed a preference for *Bos* and *Equus* over the lean saiga antelope (*Saiga tatarica*), whose bones dominated the faunal assemblage.

Nunamiut Ethnoarchaeology (Binford 1978) appeared at about the same time as another seminal work still cited extensively in faunal research, *Reindeer and Caribou Hunters* by Arthur Spiess (1979). Binford's book is arguably most often cited for its caribou body parts utility indices, and Spiess is synonymous with Table 6.13 on page 214 titled "Live Weights, Meat and Fat Yield Used in Calculating Human Occupation Size in Man-Days at the Abri Pataud from Minimum Numbers of Individual Prey Species" (Table 4 above). Binford and Spiess traded begrudging, less than favorable reviews in an issue of *American Anthropologist* (Binford 1980b: 631-632; Spiess 1980: 628-631). In his review, Binford called Spiess an idealist and a strict positivist, and he concluded that "Spiess needs to catch up to the 20th century" (Binford 1980b: 629). Binford notes that "almost half of the book is a literature survey treating *Rangifer* and man. *This is the strength of the book*" (Binford 1980b: 629, emphasis in the original). He does not mention Table 6.13 (Spiess 1979: 214), which has become the strength of the book. With a citation from his own book, Binford takes Spiess to task for making a minimum count of one individual on the basis of a scrap of one piece of bone (Spiess 1979: 183):

"This is a fairyland exercise. Once again, when I had control information from known sites occupied for known durations by known numbers of persons, I summarized the patterning as follows:

"... the relationship between MNIs recovered archaeologically and the actual consumer demand for meat will only approach a linear relationship at locations where (*sic*) consumption is from either fresh or frozen meat, and where there is no processing of animals for storage as dry meat. This relationship will only hold

when the relative placement of the site in a potential logistical chain is identifiable as a terminal node, or residential base camp [Binford 1978:449]. “ (Binford 1980b: 630-631)

This difference of opinion as to whether a scrap of one piece of bone stands for the individual from which it came or a potential logistical chain of site function and patterning seems an apt encapsulation of the transport debate. There is no recognition in Binford’s conclusions that field butchering with stone tools is a challenging and imperfect enterprise (see discussion in Frison 2004: 115) during which a scrap of one piece of bone may be missed and unintentionally transported back to a camp or residential site. But *Nunamiut Ethnoarchaeology* has acquired a legacy effect through decades of use. What has been lost is a sense that its publication was part of an ongoing debate and not an end to the debate. There is a reassuring complexity and assertiveness to Binford’s book (1978), but questions about the root of its arguments were asked at the outset:

“Like other Binfordian research forays, this one is based on a desire to explore method and theory but not on a long-term research commitment to a specific geographic area or research problem. The book will definitely become an archaeological classic-however, not for the reasons for which it was written.

“Binford's methodology is conceptually simple. He first uses the meat, bone, and fat (marrow) weights from the dissection of *only a single caribou specimen* (thus ignoring drastic seasonal fat variability in this species) to produce a series of utility indices for various caribou parts

which are to be compared with bone counts from archaeological sites.

These hypothesized utility curves, through various mathematical transformations, are fitted to detailed descriptions of site usage derived from Eskimo informants, and then compared with bone count data.

“As a theoretical study designed to raise our collective consciousness, the book is only a modest success. Its weaknesses, and its strengths, lie in the completeness of data presentation on a very narrow topic: bone frequencies.” (Spiess 1980: 631, emphasis added)

When applying the principles of *Nunamiut Ethnoarchaeology* (Binford 1978) as a universal account, we would do well to keep in mind that it is ultimately a specific study based on a single dissected sample of a single species explained by informants from a single tradition.

The debate becomes in part Hadza data versus Nunamiut data – or the last of the full-time hunter-gatherers in Equatorial Africa vs. northern hunters with skidoos, rifles and chain saws – neither of which directly addresses the issue of hunter-gatherers (at a time when all humankind were hunter-gathers) living in a temperate zone of relative abundance. For the sake of comparison, Hadza data supports the general relationship between “boning out” (stripping meat from) animal carcasses at or near the kill site and transport distances to camps:

“Despite the merits of Binford's model for the Nunamiut case, the Hadza data indicate that it cannot be applied universally. The Hadza almost always strip meat from some bones, sometimes from all bones, prior to transport. Thus, unlike the Nunamiut, their decisions about bone transport

are at least partly independent of the amount of edible tissue originally associated with each bone. Utility indices based on these amounts cannot be used to predict or explain Hadza transport patterns or, by extension, the archaeological record they produce.

“Having highlighted these differences in carcass treatment patterns, we suggest that they reflect the same underlying consideration: maximizing net nutritional benefit relative to processing and transport costs... Transport capacity (among the Hadza) is roughly matched with carcass size, except in the case of the largest animals. Bones can be, and often are, stripped and discarded at the kill as a means of reducing transport costs. Even where transport of the entire carcass is possible, field consumption by the carrying party may result in the discard of many, occasionally all, skeletal elements. In contrast, most carcasses acquired by the Nunamiut are taken in groups of up to about sixty individuals, the majority of which are destined for storage. Total carcass weight typically exceeds immediate transport capacity by a substantial margin, so at least some carcasses must be left in the field partially butchered for days or even months. These carcasses are almost always frozen by the time they are transported to base, which means that deboning or partial consumption in the field is not a realistic option.”

(O’Connell et al. 1988: 143-144)

Large animal carcasses are boned out and the meat stripped for transport (Hadza) in temperate areas, where the carcasses are not likely to freeze.

Mediterranean Spain at the Pleistocene-Holocene transition is such an area.

Other examples from Ahtna hunters in the northern boreal forests of North America support the Hadza pattern:

“The absence of caribou bones at this site, however, was attributed not to seasonal factors, but to butchering patterns, by which ‘these animals were

slaughtered and the meat dried in the hills before returning to the winter settlements' (Shinkwin, 1979: 80)" (Yesner 1989: 102)

"Yet another possibility is related to butchering patterns and meat transport: moose bones would have been far less likely to be represented in site faunal assemblages if the animals were killed at some distance from the site. The large size of moose would encourage either drying of meat at the kill location or boning out the meat in order to lighten the load before transportation back to camp, as noted by Shinkwin (1979), based on Campbell's (n.d.) Ahtna field notes." (Yesner 1989: 103-104)

Cova del Parpalló

The Magdalenian levels at Cova del Parpalló are important elements of the archaeological record in Mediterranean Spain. Cova del Parpalló is near Gandia, on the current Mediterranean coast of La Marina Alta. The site is known for its mobile art assemblage of 5034 stone plaquettes with 6245 engraved or painted surfaces (Pigeaud 2005; Villaverde Bonilla 1994, 1991/1992). These have been attributed primarily to the Solutrean centered around the Last Glacial Maximum and the Magdalenian that encompasses the terminal Pleistocene side of the Pleistocene-Holocene transition. But Cova del Parpalló also has a faunal assemblage characterized by a diversity that persisted through the Magdalenian (Villaverde et al. 1998). This record of diverse may well have been due in part to the special circumstances of the site's location, which allowed it to exploit both montane and coastal littoral zones (Villaverde *et al.* 1998: 178). Cova del Parpalló is a good place to compare subsistence patterns within a time period. The Magdalenian faunal assemblage at Cova del Parpalló is comprised of:

<i>Bos taurus primigenius</i> (aurochs)	5%
<i>Equus caballus</i> (horse)	9%
<i>Cervus elaphus</i> (red deer)	40%
<i>Capra pyrenaica</i> (ibex)	47%

(Villaverde Bonilla 1994, volume 1: 169, Table 32)

On the surface, the assemblage appears clearly skewed toward montane (*Capra*) and forested/wooded cover (*Cervus*) species by a large margin (87%), when compared to open plains adapted species (14% combined for *Equus* and *Bos*) of the coastal littoral. If we assume a total number of 100 individuals in the assemblage and convert the percentages to real numbers ($\% \times 100$), then multiply those individuals by their meat yield given in Spiess (1979: 214, Table 6.13), the assemblage takes on a different aspect:

<i>Bos taurus primigenius</i> (aurochs)	5 x 770 kilograms meat yield each
<i>Equus caballus</i> (horse)	9 x 192.5 kilograms meat yield each
<i>Cervus elaphus</i> (red deer)	40 x 187 kilograms meat yield each
<i>Capra pyrenaica</i> (ibex)	47 x 22 kilograms meat yield each

By meat yield, aurochs and horse become 40% of the faunal assemblage, while red deer and ibex drop to 60% of the total represented by the assemblage. By a count of species depicted on plaquettes in the Magdalenian levels of Cova del Parpalló, aurochs and horse are 41% of the total with red deer and ibex making up the remaining 59% (Villaverde Bonilla 1994, volume 1: 162, Table 26), mirroring the figures from meat yield for the same species. Whether Upper Paleolithic art in any way predicts or reflects the hunting practices, diets, regional ecology or faunal assemblages of the people who created it has been a subject of

research since Henri Breuil (e.g. Breuil and Carthailac 1906; Breuil 1920), who was followed by André Leroi-Gourhan (e.g. 1982). Jesus Altuna (1983, 1984, 1994) demonstrated a lack of fit between counts of animals depicted and animals identified in the faunal assemblages at Bustillo and Ekain in northern Spain. He also showed that the species depicted were not necessarily an indication of the regional ecology (Davidson 2006: 200), nor is there a direct correspondence between the choices made in the animals hunted and those depicted. Rice and Paterson (1986, 1985) added an index of prevalence of species that combined counts of bones and ordinal estimates of species abundance in site without art depictions as well as sites with art depictions. Their research indicated a correlation between the relative proportions of depictions and faunal assemblages for ten regions of France and four regions of Cantabrian Spain (Davidson 2006: 200). Davidson (2006, 1999) has questioned the actual strength and durability of these correlations. There does not appear to be a simple, direct relationship between the animals depicted in Upper Paleolithic art, including Magdalenian art, and the animals represented as bones in associated faunal assemblages. When the bones in the Magdalenian levels of Cova del Parpalló are fleshed out using the species meat yields in Spiess (1979: 214, Table 6.13) the ratio of large herd ungulates from open-areas to smaller montane and mountain valley ungulates is proportionate to their depictions in the art. It is a sample size of one time period from one site. However, Cueva del Parpalló is a site with a long tradition and well-studied art and faunal assemblage.

Subsistence Hunting

The nature of subsistence hunting for medium to large ungulates is that it happened away from most of the palimpsest cave sites that have been excavated. Given the uniformitarian presence of scavengers, blow flies, maggots, vermin, and disease incubators, we should not expect to find evidence of what people killed and butchered, or the way they processed that kill, where we find evidence of the places those people lived. The more fortunate and successful a group is in their hunting, the less likely they are to carry away evidence of that success. For example, if a group kills an aurochs, Paleo-Indian evidence from the Northern Plains of North America indicate that it would not be unusual to carry away the choice parts, including tongue, liver, and fat, fat-marbled meat (Frison 2004: 113-117), process what they could at the site or near to the site – jerky, pemmican, rendered fat, bones boiled for grease (Frison 2004: 224; Prince and Steckel 2003: 365, 375; Grønnow 1986: 74-78; Wheat 1967: 50-51; Wissler 1920: 27-29) – and leave the heavier but less valuable skeletal elements at the butchering locale.

Wissler's study of Blackfoot buffalo hunting, at a time when his information came directly from sources who would have been buffalo hunters, offers insights into butchering practices on large prey species in a temperate, productive environment (Wissler 1910: 41-42). According to Wissler's informants, when a kill was made far from camp or when several animals were to be transported, the field processing was referred to as "light butchering," in which the bones were left behind at the kill site. Leg bone marrow and sometimes rich organ meat (especially brains) were eaten during field dressing.

“While the Blackfoot had no cereal from which such bread substance could be made, they found a substitute in a compound of berries and flesh generally known as pemmican. For this, the best cuts of buffalo were dried in the usual manner. Then they were pounded on a stone until fine.

Hammers, as previously described, were often used for this purpose. Just before pounding, the pieces of dried meat were held over the fire to make them soft and oily. Marrow and other fats were heated and mixed with the pounded meats, after which crushed wild cherries were worked into the mess ... The whole was then packed into parfleche or other bags, a compact sticky mass, easily preserved and good for eating without further preparation ... One pound of pemmican is equal to five pounds of meat” (Wissler 1910: 22-23)

Wissler is also articulate about the importance of fat to hunter-gatherer diets. While his account is specific to the North American *Bison bison*, it may help explain the preference for large bovids at the Magdalenian site of Saint-Germain-la-Rivière.

“A special form of back-fat, used by the Blackfoot and other tribes, has been given the name "depuyer" (depouille), a good description of which has been given by Hamilton:

‘Another important article of food, the equal of which is not to be had except from the buffalo, is "depuyer" (depouille). It is a fat substance that lies along the backbone; next to the hide, running from the shoulder-blade to the last rib, and is about as thick as one's hand or finger. It is from seven to eleven inches broad tapering to a feather edge on the lower side. It will weigh from five to eleven pounds, according to the size and condition of the animal. This substance is taken off and dipped in hot grease for half a minute, then is hung up inside of a lodge to dry and smoke for twelve hours. It will keep indefinitely, and ... (it) is eaten with lean and dried meat, and is tender and sweet and very nourishing, for it seems to satisfy the appetite ...

(T)he Indians would take some dried meat and some depuyer to live on, and nothing else, not even if they were to be gone for months.’”

(Wissler 1910: 24 citing Hamilton 1905: 32)

In the specific context of Iberia, Freeman noted that although bovids and equids made up only 9% of the NISP total at a site, and only 27.3% of the MNI totals, the bovids and equids would have produced 58.9% of the site’s available meat (Freeman 1973: 36). *Cervus elaphus* (red deer) comprised 86.5% of the NISP total and 45.5% of the MNI total in the same faunal assemblage. But they would have provided only 30.1% of the estimated meat yield. Freeman called it the “pitfalls inherent in reasoning about diet when the only available data re the relative abundances of bone fragments from each species” (Freeman 1973: 36)

Accounts from summer reindeer (caribou) hunting camps in Greenland reinforce the preference to process successful hunts as much as possible before transport – and further support that large animal bones may be under-represented in faunal assemblages excavated at residential sites:

“Agnethe Rosing ... employed a special technique of cutting the lumps of meat into thin, but very big pieces. In this way the meat could be dried in only a couple of days, in the sun and the wind, and could be preserved for a long period ... At the end of the butchering process Agnethe smashed the richly myelinated bones ... The bones were cooked in a pan to get hold of the marrow and the bone fat. Unfortunately it was not possible to obtain these bones left by Agnethe’s work in 2003 because ... (w)hen the authors had the opportunity to go back to collect the bones in 2009, they could not be found. They were not visible on the surface and possibly had been thrown into the river.” (Pasada and Odgaard 2011: 36)

Recent theory works to apply the general tenets of behavioral ecology (Winterhalder and Smith 2000) and optimal foraging (Hawkes et al. 1982; Jochim 1983; Smith 1983) to two more specific behavioral models: Central Place Foraging Patch Choice (Orians and Pearson 1979) and Central Place Foraging Prey Choice (Cannon 2003), which deal with decision-making to maximize output and input ratios of energy, usually measured in Kcal (Arroyo 2009). The decisions involve which species should be hunter, in what order should they be hunted, and which anatomical parts should be transported to base camps (Arroyo 2009). The models assume a logical preference for species that offer more calories input compared to calories expended in their acquisition. Therefore, large prey like aurochs and horse will be hunted in larger catchment areas. If hunters have to travel farther to make a kill, then they will butcher the carcass more intensely in order to maximize the energy contribution of each load being carried (Arroyo 2009). Hunters residing in a montane or wooded area are likely to hunt montane and woodland associated species – but only if they do not have the option decision hunt open-area species whose habitat distance is offset by their energy yield (Arroyo 2009: 28). These precepts are consistent with the faunal data from Cova del Parpalló.

Hunters at Cova del Parpalló hunted red deer and ibex near the site, but they traveled to the coastal littoral to hunt aurochs and horse. The more intense butchery predicted by the models helps to account for aurochs and horse being only 14% of the NISP count for Magdalenian levels at Cova del Parpalló. However aurochs and horse potentially would have provided the much more meat

yield, which is why hunters from Parpalló made the trip.

“In order to assess how profitable it is to invest time in butchering an animal, Cannon (2003) defines a theoretical processing function that relates the additional time used to butcher the carcass once the prey is in an appropriate condition for its transport (i.e., after handling time) with the energy that can be transported to the base camp. In all cases, it is assumed that a physical limit for transport exists where the animal cannot be carried away whole, and therefore the more useful parts must be chosen. This function begins with an initial value, equal to the maximum energy that can be transported without any butchering, decreasing monotonically afterwards, because the butchery process will commence with the most productive parts, those that offer the greatest amount of meat for the least processing time, and will finish with the high cost/low yield extraction of bone marrow. In the case of small prey, however, the processing function is reduced to a single point, equivalent to the total caloric yield of the animal, which can be carried whole to the camp.” (Arroyo 2009: 28)

This is essentially an update of Duncan Metcalfe and Renee Barlow’s model exploring the optimal trade-off between field processing and transport (Metcalfe and Barlow 1992). Its explicit reduction of small prey processing to a single point equivalent to the total caloric yield of the animal “carried whole to the camp” suggests an answer to why, as the Magdalenian progresses during the Pleistocene-Holocene transition, the number of lagomorphs in faunal assemblages swamps the counts of all other species in Mediterranean Spain. In writing about the end of the Upper Palaeolithic in Mediterranean Spain, Villaverde acknowledges that the “presence of rabbits is overwhelming in comparison to that of other taxonomic groups ...” (Villaverde et al. 2012: 8).

European Rabbit (*Oryctolagus cuniculus*)

Haws notes that even though rabbit ranks low in the overall diet based on meat weight, “the undeniable fact is that their remains do not just dominate assemblages, they swamp them in many cases. People went to some effort to procure them on a large scale. Why?” (Haws 2003: 57).

European rabbit (*Oryctolagus cuniculus*) dig burrow networks called warrens, where they spend most of their time when not feeding. In the historic era, poachers covered over or filled in most of the apparent warren openings and sent a captured ferret down one opening. Rabbit were netted or clubbed as they ran out the burrows left open. If the poacher’s need for stealth is not an issue, smoke from fired brush or rotted wood put down an opening and covered over eliminates the need for a ferret (see Osborne and Winstanley 2006; Manning 1994; Bailey 1988). Poaching accounts of rabbit procurement suggest rabbit were targeted specifically because they did not require special effort.

For all their *r*-selectedness, rabbit are not a reliable subsistence resource. According to data from Western Australia, European rabbit on average have population boom to bust cycles every seven to 10 years. Subsistence intensification that depends on rabbit would find a steep population drop-off toward the end of that cycle – not a gradual, predictable cline during which rabbit could be replaced by other resources.

As previously noted, young rabbits disperse up to 1500 meters from their home warren and establish new warrens as rabbit litters mature. There may be four to eight warrens within a square kilometer. Rabbit warrens and rabbit

behavior makes them relatively easy to find and to exploit in large numbers.

“Cottontails (note: North American rabbits) hide in brush or remain visible at or close to holes into which they can dive at any indication of danger. ... (A)t a very early age I was shown ... a green branch with a forked end could be inserted into the hole until it touched the rabbit. A few twists anchored it firmly enough into the rabbit's fur so that the animal could be pulled to the surface.” (Frison 2004: 191)

Assuming that exploited European rabbit warrens would have been similar, then the large accumulations of rabbit bones in Magdalenian faunal sites could be viewed as the remains of a convenience resource harvested by social groups moving between territories.

Kill Sites

Western Europe has open-area kill sites – locations where specific large prey species have been targeted by hunters in large numbers – stretching through time from the Mousterian (Wynn and Coolidge 2003) to the Mesolithic (Helmer and Monchot 2006; Alday and Cava 2006; Aura et al. 2011: 353). The evidence suggests that as with Paleo-Indian buffalo jump and other kill sites from North America (Frison 2004: 83-88, 95-99), by Upper Paleolithic hunter-gathers were efficient communal hunters of large animals (Olsen 1989). Kill sites specialize on a single species (e.g. Helmer and Monchot 2006). The opportunity to communally hunt a large herd (usually a seasonal aggregation of aurochs or horse related to seasonal migration or breeding season) of large animals would have made it economically feasible for hunter-gatherer groups in montane regions like La Marina Alta to travel to the edge of the Mediterranean littoral – or to the

southeastern edge of the Meseta, when the effects of rising sea level inundation negated the open plains and oak *mottes* habitat of the littoral. One of the elements that kill sites in the Paleo-Indian period of North America and the Pleistocene-Holocene transition of western Europe have in common is *in situ* processing of the carcasses (Frison 2004: 79-87; Helmer and Monchot 2006). Animals were butchered at the kill site and their energy-value in meat was transported to residential sites, whether these were aggregation camps, base camps, or home territory caves and rock shelters.

The concept that kill-sites are equated with communal hunting is important. As noted above, communal hunts mean that individuals from multiple social groups temporarily fused into a separate, cooperative entity larger than the one in which they lived their daily lives (Hill 2007: 285; see also Hofman 1994: 286). In the context of the Pleistocene-Holocene transition, these fused social groups would have provided a momentum, an impetus, a *deus ex machina* for forming or renewing risk mitigating alliances, marriage networks, trade networks, and entities for dispute resolution. Communal hunts in and of themselves are a form of aggregation (Hofman 1994), but they can also be the subsistence base for larger social aggregations (Bamforth 1991) – contexts for converting the largesse of good hunting luck into reciprocal debt obligations, through feasting or sharing, that can be redeemed in times of need or bartered in times of social friction.

Moreover, the ability to create social aggregations and to plan and execute communal hunts demonstrates an ability to communicate beyond the confines of family-based groups or even territorial entities. Cashdan's (1983) definition of

economic territories essentially equates geographic parameters with their resident human social groups. Being able to communicate beyond any one social group also means that geographic areas are in some way stitched together by something larger than the presence of the social groups occupying them. The scope of these extended communities helps to explain Mediterranean shells appearing in Switzerland, southern Germany, and the Rhine Valley (Jochim et al. 1999).

Although separated by details, Iberian researchers note a significant degree of parallelism among the regions as seemingly disparate and geographically removed from each other as the Portuguese Estremadura, Cantabrian northern Spain and the Mediterranean of southeast Spain (Aura et al. 1998: 101). The nature of the connections between these peripheral coastal regions separated by the topography of high cordilleras and the often inhospitable interior Meseta has been called one of the unanswered questions of Iberian archaeology (Aura et al. 1998: 101):

“Further research is clearly required along the valleys of the great rivers of the (Iberian) Peninsula, the Ebro, Duero, Tagus and Guadalquivir, as well as along the coastal plains of Galicia, western Andalucia and Algarve. Developments such as the recent discoveries of late Upper Paleolithic habitation sites in Cadiz León and Lugo and open-air rock art in the interior provinces of Segovia, Salamanca and Beira Alta, may help prehistorians forge the links of prehistoric social contacts that transcend the ecological differences among the peripheral regions, in a manner analogous to the artistic similarities between southern France and Cantabrian Spain on the one hand and Mediterranean Spain on the other.” (Aura et al. 1998: 101)

Nodes of Communication

Looking from La Peña de Estebanvela north to the Pyrenees (Cacho et al. 2012), there is evidence of contacts in the commonality of the most characteristic motif in the portable art found at the rock-shelter, which is also found at a litany of French sites: Gourdan (Haute Garonne), Espelugues (Haute Pyrénées, Dufaure (Landes) and Rhodes (Ariège). From Rhodes at Ariège, the contacts extend even further from the Meseta to Pages (Lot) – about 80 kilometers from Les Eyzies-de-Tayac-Sireuil and the heart of the Franco-Cantabrian refugium in the Périgord-Dordogne region (Cacho et al. 2012). The similarity in portable art strongly suggests contact with sites as distant as Rochedane on the Swiss border. This suggests the existence of long-distance contacts with these Magdalenian groups south of the Duero Valley (on the northwest Meseta between Madrid and Burgos). Working from the Meseta south to the Mediterranean, Cacho and Perez (1997: 272) look at similarities of art and see the connecting river valleys as “natural passages to the coast” (“*pasos naturales hacia la costa*”) – particularly in the Valencia area that forms the northern border of La Marina Alta.

CHAPTER 6

CASE STUDIES

H₁: Foragers in the Mediterranean region of Southeastern Spain adapted to the consequences of macroclimatic change by extending their social networks to gain access to new subsistence resources and by recombining traditional relationships to shifting circumstances.

Testing the working hypothesis of this project requires establishing three criteria:

1. The consequences of macroclimatic change in Mediterranean Spain, which is to say establishing the consequences of littoral inundation during the Pleistocene-Holocene transition.
2. That extending social networks and gaining access to new subsistence resources had the at least the potential of helping to alleviate the consequences of littoral inundation.
3. There was a resource pull within the distances parameters suggested by Whallon's model for social networks and non-utilitarian mobility (Whallon 2006) to merit the compromises and management outlays intrinsic to creating and maintaining new social relationships.

Ethnographic accounts from nineteenth century Blackfoot (Niitsítapi) bison hunters on the northern plains of North America (Wissler 1910: 24, 41-42), twentieth century Hadza hunters from equatorial Eastern Africa (O'Connell et al. 1988), and Athabaskan (Ahtna) moose hunters in the northern boreal forest of

North America all indicate that kills of large prey, and especially large prey successfully hunted outside the immediate vicinity of a camp or residential site, are under-represented in NISP and MNI counts of faunal assemblages. The ethnographic accounts cited crosscut regions, cultures, and time periods. These are the conditions identified by Jochim (1976) as necessary in order to be applied as general principles for hunter-gatherer subsistence studies rather than applicable in specific cases only. The outcome of the Blackfoot, Hadza, and Ahtna accounts is an understanding that quantifying NISP or MNI representation within a faunal assemblage does not in and of itself accurately reflect the diet of the hunter-gatherers who contributed to the faunal assemblage.

As noted previously, the Magdalenian site of Saint Germain-la-Rivière (circa 15,000 bp) in Southwest France presents the rare opportunity to compare NISP and MNI analysis of a faunal assemblage with isotopic analysis of human bone collagen from the same site. The assemblage also included wolf bones that were submitted for isotopic analysis in order to compare carnivore diet with human diet at the site (Drucker and Henry-Gambier 2005).

Species group	NISP (%)	MNI (%)	MW (%)
Saiga antelope/reindeer	89.7	77.4	17.3
Large bovids	3.8	10.5	64.5
Horse	6.4	12.1	18.2

Table 5. Faunal Assemblage from Saint-Germain-la-Rivière. MW = Species MNI x Species Mean Meat Weight from Spiess (1979: 214, Table 6.13). (Drucker and Henry-Gambier 2005: 31, Figure 7)

Meat Weight (MW) percentages calculated from the faunal assemblage at Saint-Germain-la-Rivière most closely match proportions of dietary protein sources calculated from isotopic analysis of the human bone collagen from Saint-Germain-la-Rivière. (Drucker and Henry-Gambier 2005: 31-32). Although saiga antelope/reindeer accounted for 89.7% of the assemblage by NISP and 77.4% by MNI (Table 5), calculating human diet from both stable isotopes and MW percentages strongly suggests that the importance of saiga antelope/reindeer in the diet of the human hunters of Saint-Germain-la-Rivière must be de-emphasized.

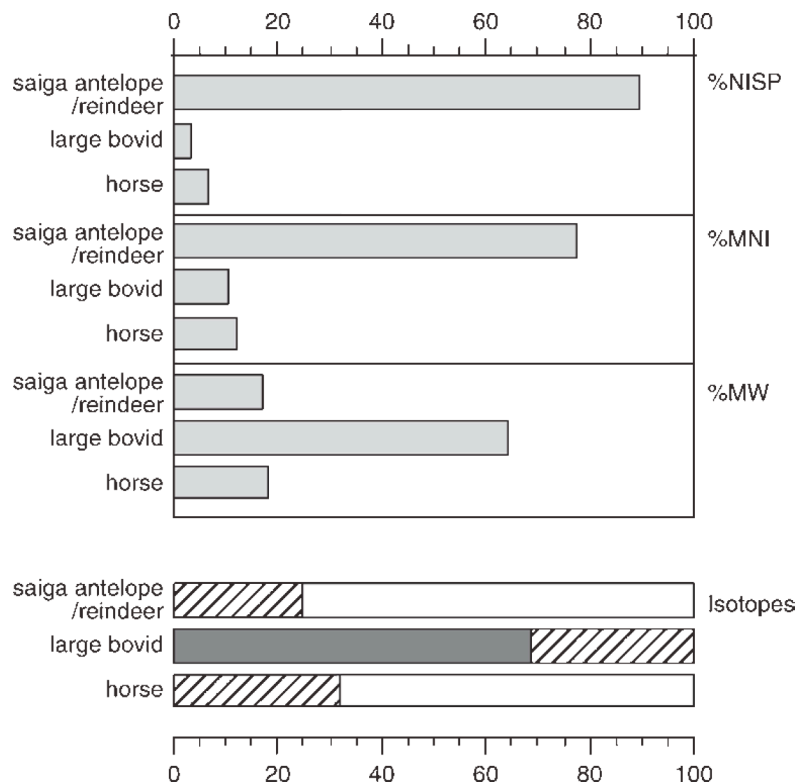


Figure 16. Comparing isotopic analysis of human bone collagen at Saint-Germain-la-Rivière. (Drucker and Henry-Gambier 2005: 31, Figure 7)

Comparing carbon and nitrogen isotope ratios for the female skeletal elements from Saint-Germain-la-Rivière with those for available bovids and horse indicates that meat of large terrestrial herbivore species were her primary source of dietary protein (Figure 16)..

Stable isotope ratios for a wolf from the assemblage indicate that salmon was available and consumed by carnivores in the area, salmon consumption by the human analyzed was not significant. The calculated proportions of protein sources in the human diet at Saint-Germain-la-Rivière differ from those of coeval animal predators. This suggests that large herbivores (bovids and horse) were targeted prey species and not the result of an opportunistic pattern of subsistence (Drucker and Henry-Gambier 2005: 32).

“A (modified) linear mixing model ... and meat percentage estimates give a more precise picture of human exploitation of protein sources than do traditional faunal analyses alone. Meat of saiga antelope and reindeer were not as important to the woman’s diet as indicated by MNI counts. Although saiga antelope provided the largest amount of bone remains, meat percentage estimates from the faunal assemblage of SGR fit the isotopic reconstruction of the woman’s diet ...

“This example highlights the utility of meat weight calculation to investigate the specific contributions to human diet. At SGR, the overwhelming numerical occurrence of *saiga antelope bones can be explained by the ability to transport the entire carcasses of such small prey.*”

(Drucker and Henry-Gambier 2005: 32, emphasis added)

A similar conclusion was reached at the Solutrean type-site of Solutré in Southwest France, which is also a kill site where *Equus* were targeted:

“The significance of wild horses ... in the economy and ritual life of Upper Palaeolithic-Europeans is attested to by their predominance in cave art ... and their regular occurrence in faunal assemblages... Horses rarely dominate the species lists in western Europe, however Like bison, aurochs, and mammoth, *horses may be frequently under-represented in occupation sites*, in comparison to reindeer and other smaller game, *because of a reluctance on the part of the hunters to drag heavy bones of large game back to the base camp unnecessarily.*” (Olsen 1989: 295-296, emphasis added)

Only one kill site is acknowledged in Eastern Spain. The Mendandia rockshelter (layer IV) located on the edge of the upper Ebro basin and the Meseta appears to have specialized in exploiting *Bos primigenius* (Aura et al. 2011). Layer IV at Mendandia is attributed to the Mesolithic but may date earlier.

Bones at La Peña de Estebanvela (Magdalenian site on the Meseta) do not show signs of thermal alteration nor are they broken, suggesting that formation of the faunal assemblage was incidental to subsistence activities and not the direct result of subsistence. The bones were not targeted for extracting marrow or grease rendering. Meat was boned-out before cooking (Cacho et al. 2012: 40).

Anatomical profiles and the taphomic analysis showing bones were generally neither broken open nor thermally altered (Yravedra 2007) suggest that even large prey was transported whole to La Peña de Estebanvela – which in turn suggests that all prey was hunted within a 10-kilometer radius of the site (Cacho et al. 2012: 40). Ungulates aged four to six years appear to have been preferentially hunted, with only a few infant and juvenile specimens in the faunal assemblage. This selective hunting pattern has been interpreted as offering a

subsistence advantage, the relative maturity meaning more fat accumulation (Cacho et al. 2012: 40). The pattern also serves to help confirm the inference of intentional targeting by Magdalenian hunters at Saint-Germain-la-Rivière (Drucker and Henry-Gambier 2005: 32).

The species common to most faunal assemblages on the Iberian Peninsula, including Mediterranean Spain and the Meseta, and their suggested primary habitat during the Pleistocene-Holocene transition are (in alphabetical order):

<i>Bos primigenius</i>	Aurochs	Savannah habitat
<i>Capra</i> sp.	Ibex/Chamois	Montane habitat
<i>Cervus elaphus</i>	Red deer	Woodland habitat
<i>Equus</i> sp.	Horse	Savannah habitat

Unfortunately, from the view of understanding behavioral and habitat specifics, no truly wild horses exist in natural settings today. The Przewalski horse has not been observable in its natural habitat since about 1966 (Bokonyi, 1974 cited in Olsen 1989: 317). There are, however, known populations of feral horses, and some generalizations about behavior and social organization can be drawn from data collected for feral horses, wild Asiatic horse, and even zebras (Olsen 1989: 317).

“We know from strong similarities in the social organization, mating behavior, and migration patterns of wild Asiatic horses, feral horses, and zebras (excepting Grevy’s zebra) that these patterns must have been established in a common ancestor. Extrapolating backward to Late Pleistocene horses ... seems a reasonable and worthwhile endeavor.” (Olsen 1989: 317)

Horse are usually found in bachelor groups or family bands consisting of a single stallion, his mares, and their offspring. Large aggregates of horse tend to form when resources are relatively concentrated in rich areas (Olsen 1989) like seasonally maturing grasses on the open plains.

At Doñana National Park, the red deer (*Cervus elaphus*) population is more widespread and widely dispersed than those of the other large herbivores (Rogers and Myers 1980: 560). As a primary browser, red deer prefer more cover than large herbivores such as horse and aurochs and generally found in smaller groups than horse or aurochs any given season of the annual cycle.

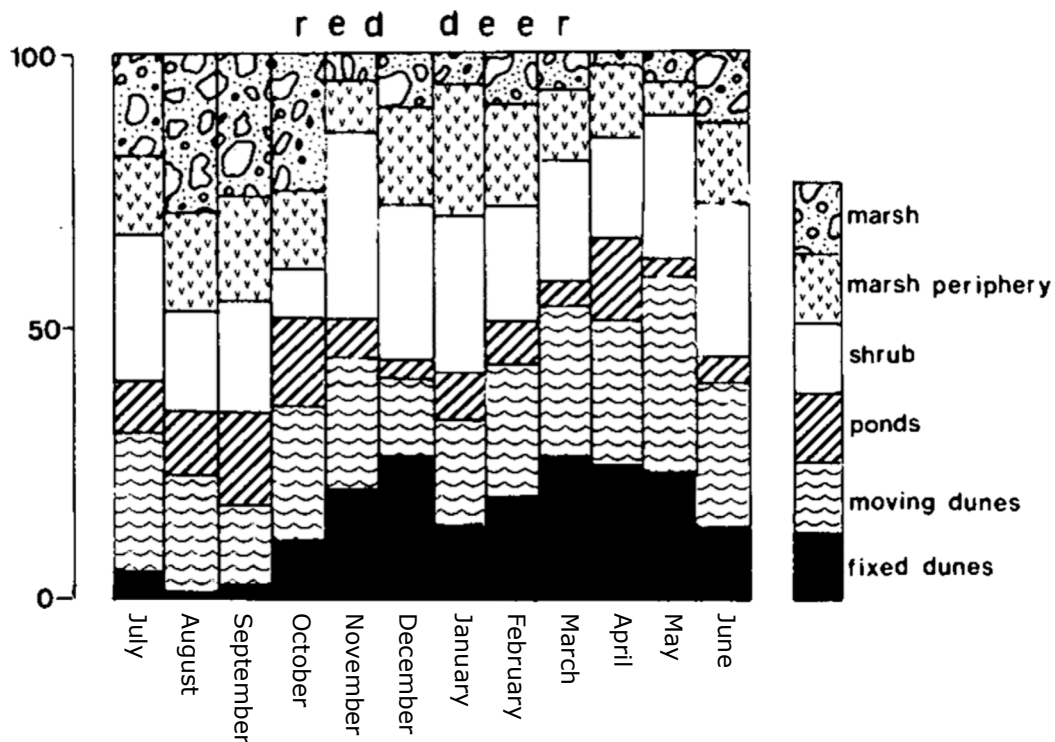


Figure 17. *Cervus elaphus* annual habitat-use cycle at Doñana National Park. After Braza and Álvarez 1987: 366, Figure 3.

In observational studies of red deer at Doñana National Park (Figure 17), the populations were found in cover at the edge of ponds, in shrub areas, in cover at the periphery of marshes, and in the marshes themselves.

For the purposes of this study, *Capra* sp. includes both *Capra pyrenaica* (ibex) and *Rupicapra rupicapra* (chamois). They are found in the same types of montane habitats, and the meat yield difference in kilograms is negligible. The dressed weight of ibex is 22-kilograms, and chamois dress out at 19-kilograms. For this study, both will be counted as having a meat yield of 22-kilograms.

Bos primigenius (aurochs) are relatively rare in the faunal assemblages of Mediterranean Spain and the Meseta – the exception being the Mendandia rockshelter (layer IV) Mesolithic site located on the edge of the upper Ebro basin identified as an aurochs kill site. It is one thing to say that aurochs are under-represented in the faunal assemblages in which aurochs are found, but it is quite something else to use highly probable under-counts as a rationale to include an estimate of aurochs in faunal assemblages where they are not found. Only actual counts of aurochs NISP and MNI are used in this study.

Taking the precedent from Saint-Germain-la-Rivière and calculating estimated Meat Yield and Winter Fat Content components (values from Spiess 1979: 214, Table 6.13) to the overall faunal assemblages at Cova del Parpalló (circa 18,000 bp to 10,000 bp) on the Mediterranean littoral and La Peña de Estebanvela (circa 13,000 bp to 10,000 bp) on the Meseta suggests an emphasis on large savannah herbivores (bovids and horse) over woodland/montane (red deer and ibex/chamois) species from representation in the NISP and MNI data.

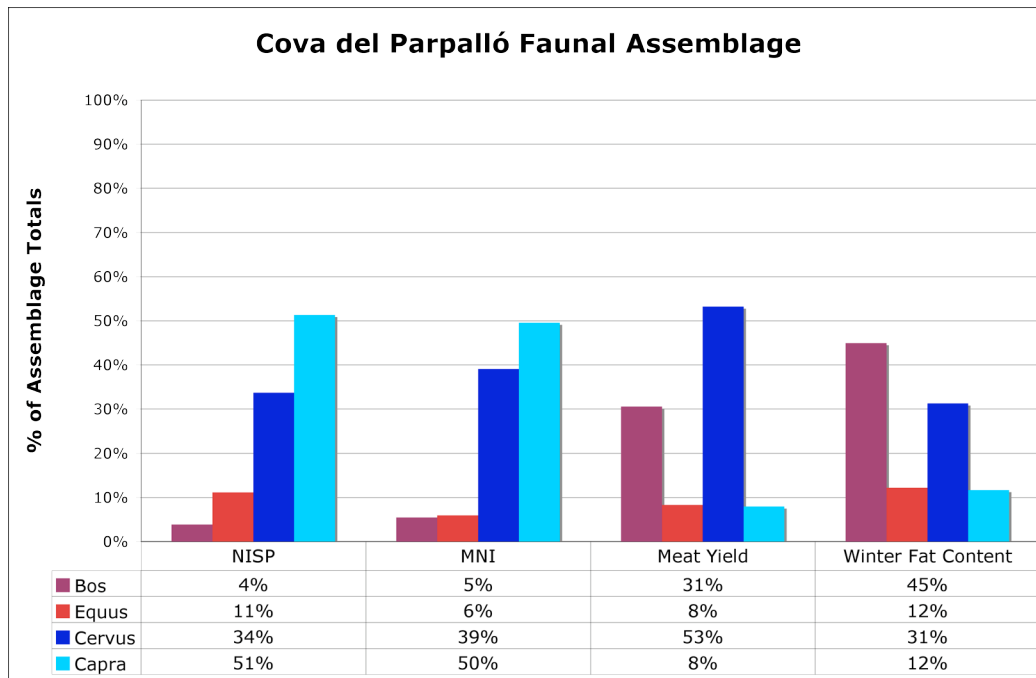


Figure 18. Reconstructed faunal assemblage at Cova del Parpalló. Including potential meat yield and winter fat content increases the importance of *Bos* and *Equus* to littoral hunter-gatherers.

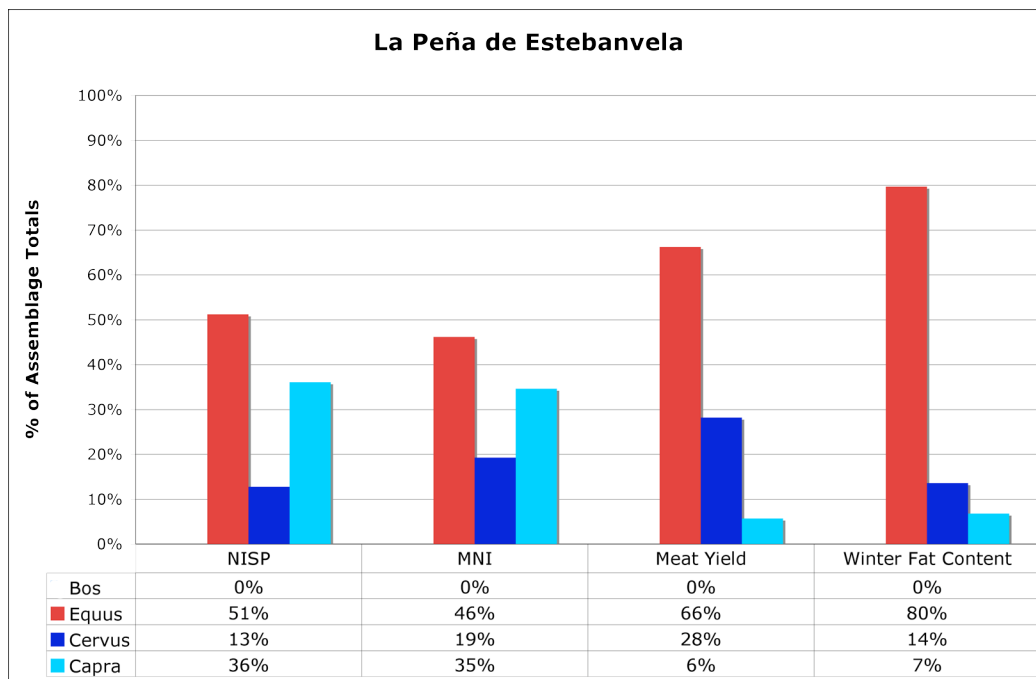


Figure 19. Reconstructed faunal assemblage at La Peña de Estebanvela. Including potential meat yield and winter fat content increases the pull toward the Meseta for littoral hunter-gatherers.

Calculating the Winter Fat Content component for each faunal assemblage reinforces the pattern established by Meat Yield percentages. Bovids and horse and would have been Mediterranean Spain's largest herbivores in the Late Upper Paleolithic and primary sources of fat, a higher value nutrition element for hunter-gatherers than general meat calories (Speth and Spielmann 1983). Fat was the most concentrated type of dietary energy available on the Late Upper Paleolithic landscape – fattier foods have higher energy yields for each unit of weight than other foods (Jochim 1981: 82). Meat with a fat content of 5% or more per edible portion has 10% or more of raw protein per portion (Jochim 1981: 82). Therefore, we can assume that fat content would have been a factor in optimal foraging decisions on which territories to hunt using available information for prey species locations and accessibility to those locations.

“The problem of obtaining enough fat is crucially important and may be a mechanism for exploring group mobility in the past. (B)oth the quantity and location of animal body fat changes throughout the year, according to season. This also varies between species, and in a fat-focused strategy this would impact on patterns of carcass transport and on butchering and processing strategies. “ (Pryor 2008: 167)

Organizing the overall assemblages at Cova del Parpalló (Figure 20), centrally located on the littoral, and La Peña de Estebanvela (Figure 21) on the Meseta by habitat offers a potential insight into optimal foraging decisions based on Meat Yield and fat content, measured by Winter Fat Content.

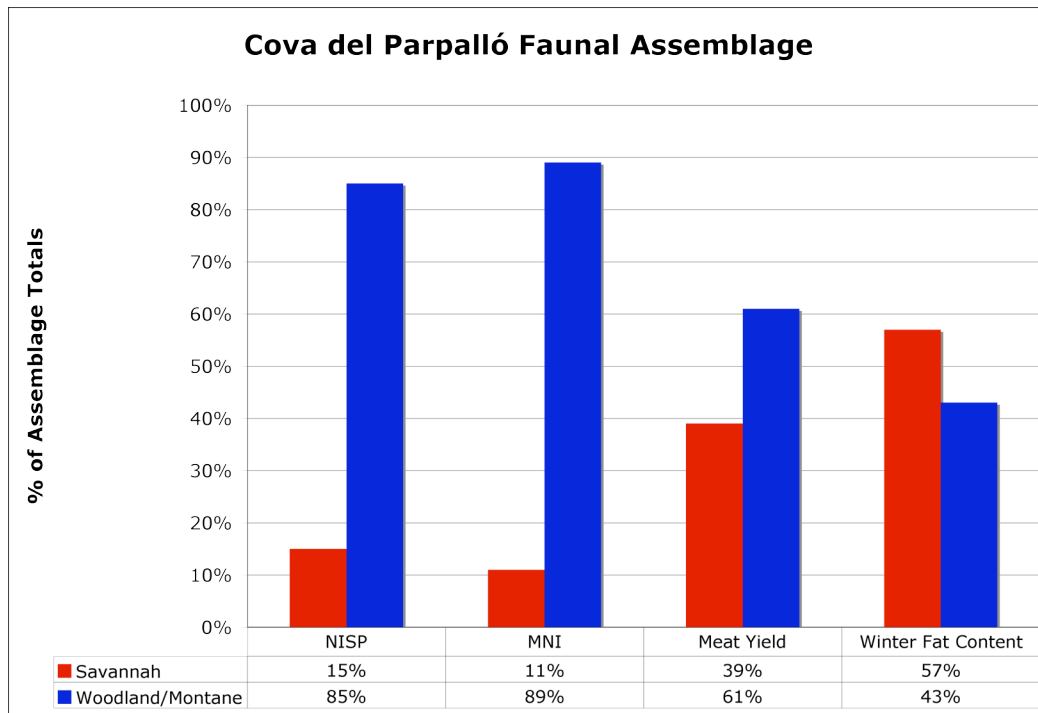


Figure 20. Littoral by savannah and woodland/montane prey habitats.

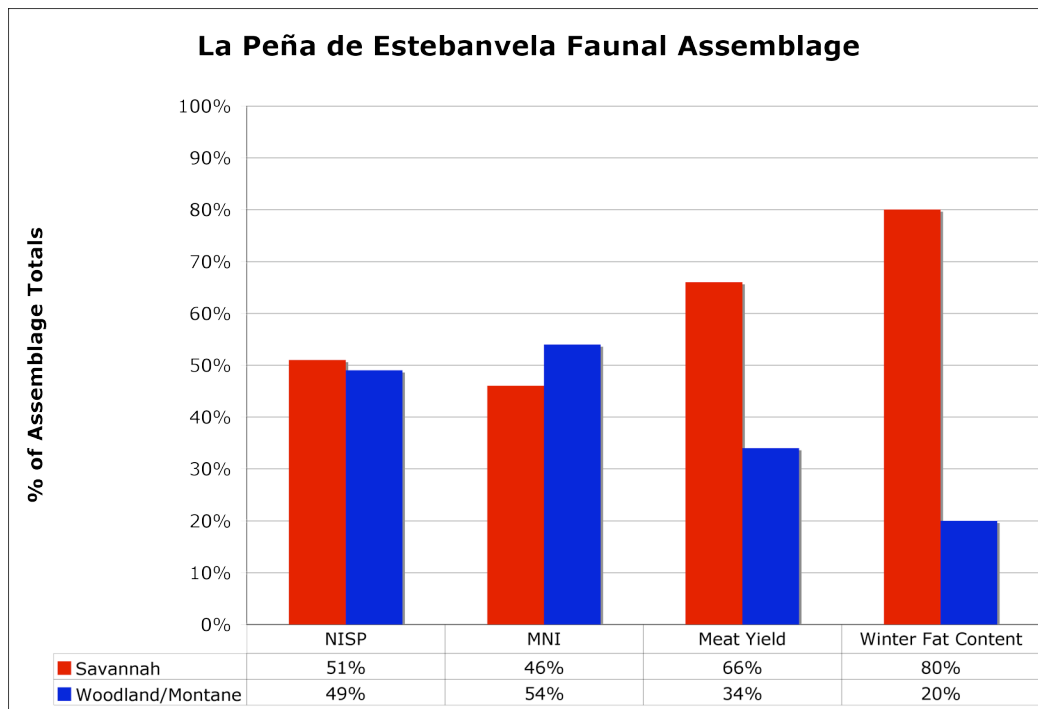


Figure 21. Meseta by savannah and woodland/montane prey habitats.

It is also possible to reduce the savannah and woodland/montane habitat dichotomy to its most representative constituent parts: *Equus* to represent the savannah and *Cervus* to represent woodland/montane habitats. Although *Capra* is a significant proportion of the NISP and MNI values at both Cova del Parpalló and La Peña Estebanvela, *Capra* has a potential Meat Yield of only 22 kilograms per adult male – about 12% of the Meat Yield available from an adult male *Equus* or an adult male *Cervus*, with an equivalent decrease in Winter Fat Content.

To calculate an Equus-Cervus Ratio (Eq-Cv Ratio) representing Meat Yield and fat content potential from savannah and woodland/montane habitats, this study used the following formula and value inputs.

1. $\text{Eq-Cv Ratio} = \text{Equus} / (\text{Equus} + \text{Cervus})$ for Mediterranean and Meseta NISP values from dated levels, circa 18,000 bp to 10,000 bp.
2. Mediterranean NISP values and dated archaeological levels are taken from Nadal et al. 2005: 316-319. Total 38 dated levels from 15 sites.
3. Meseta NISP values and dated archaeological levels are taken from: Cacho et al. 2010: 130-131, Table 5
Domingo and Utrilla Miranda 2003
Total five dated levels from two sites.

The Eq-Cv Ratio for radiocarbon dated levels on the Mediterranean littoral and the Meseta are shown in Figure 22. It should be noted that only *Equus* is plotted. In the Eq-Cv Ratio, *Equus* values and *Cervus* values mirror each other. If *Equus* is 75%, for example, then *Cervus* is 25%. The two values will always result in a total of 100%.

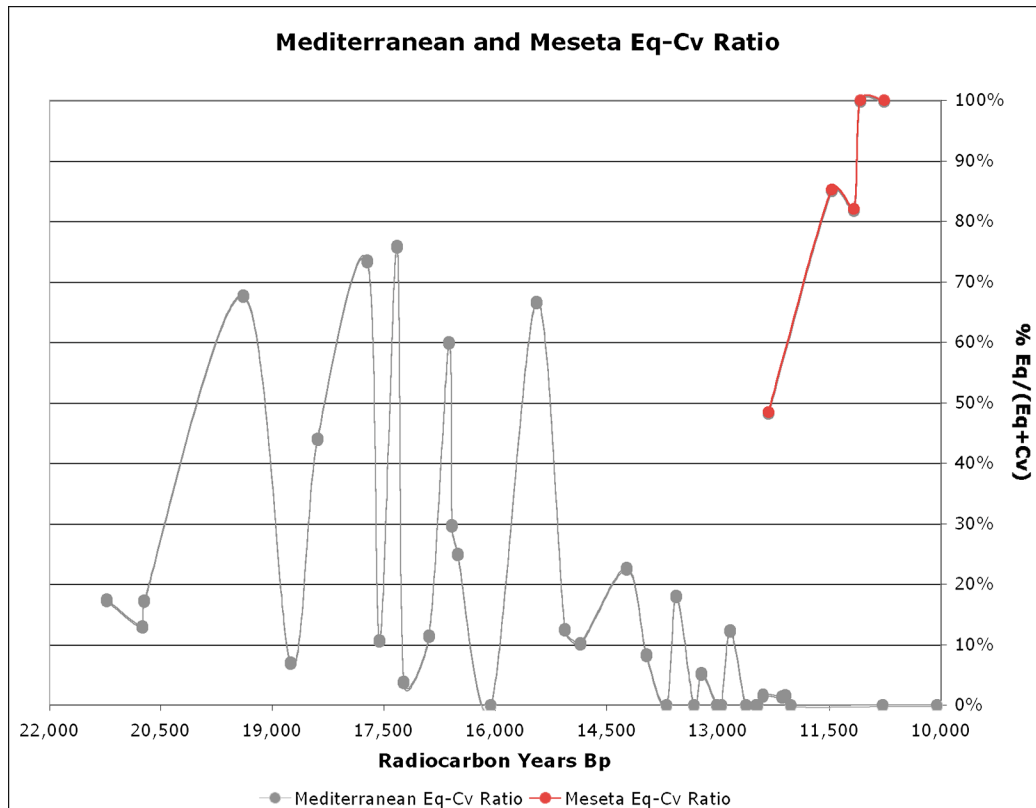


Figure 22. Equus-Cervus Ratio for the Mediterranean littoral and the Meseta. Only Equus is plotted.

At about 13,000 bp, it appears that the Mediterranean littoral reached a tipping point. The Eq-Cv Ratio (Figure 22) shows savannah species (represented by *Equus* in the plot) greatly diminished in faunal assemblages (NISP data) in the Mediterranean region as hunting for savannah species began on the Meseta and climbed rapidly. This relationship between savannah habitat species diminishing on the Mediterranean littoral and increasing on the Meseta becomes even more apparent when the Eq-Cv Ratio values are condensed into regions and displayed before and after the marker date of 13,000 bp (Figure 23).

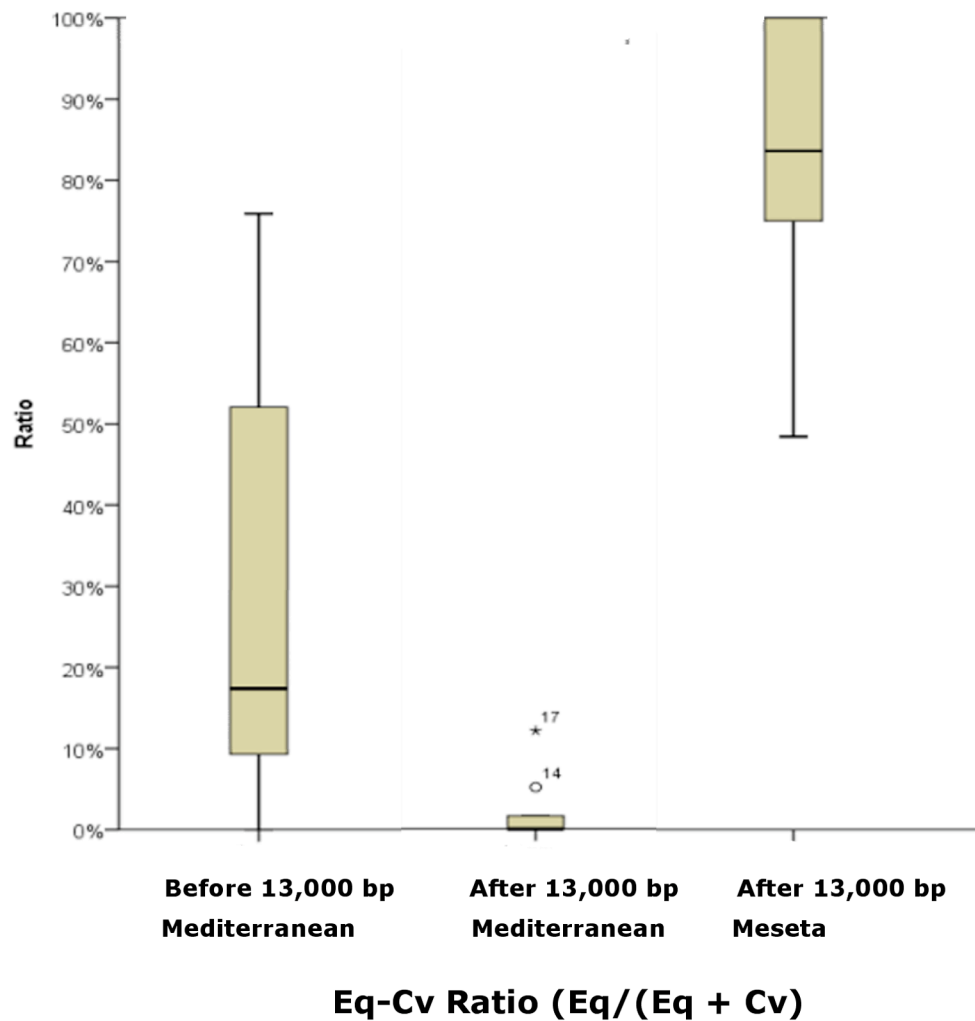


Figure 23. Eq-Cv Ratio by regions. Shown before and after the apparent marker date of 13,000 bp.

It is also significant to note that by the marker date of 13,000 bp, the Mediterranean littoral had lost an estimated 44% of its landmass (see Figure 4, page 45) from the lowest point of sea level at the Last Glacial Maximum (LGM), circa 18,000 bp. Moreover, the landmass loss was unequal on a north to south axis with Capo de la Nao at the center – roughly between Cova del Parpalló and

Cova de les Cendres. Due to the geological structure of the coastal shelf, the littoral north of Capo de la Nao maintained more of its landmass for a longer period of time than the littoral south of Capo de la Nao. Cova de les Cendres may have been more sensitive to coastal inundation than Cova del Parpalló. But it should be noted that Cova del Parpalló is located farther inland than Cova de les Cendres, and the two sites have different chronological trajectories.

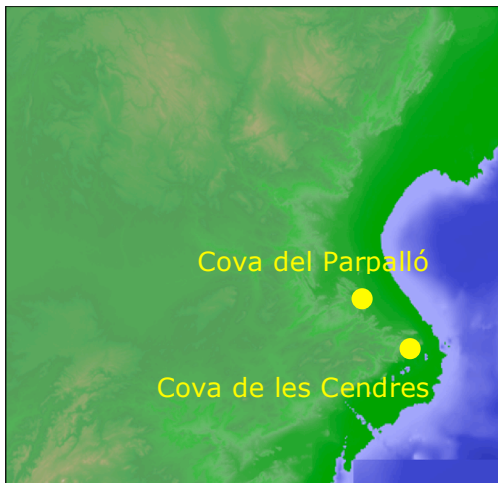


Figure 24. Mediterranean littoral at 18,000 bp.

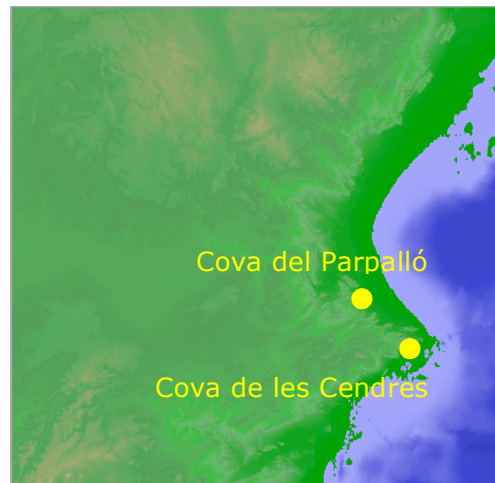


Figure 25. Mediterranean littoral at 13,000 bp.

Lithic Evidence

The accumulation frequency of retouched lithics before and after the marker dated of 13,000 bp remains fairly consistent through time on the Mediterranean littoral, but the rapid climb of the Eq-Cv Ratio on the Meseta after 13,000 bp is not reflected in the frequency of retouched lithics within lithic assemblages on the Meseta (Figure 26). The likely explanation is that the increasing exploitation of savannah adapted species on the Meseta after about 13,000 bp was accomplished by what Binford (1980: 10) referred to as “logistically organized collectors” who

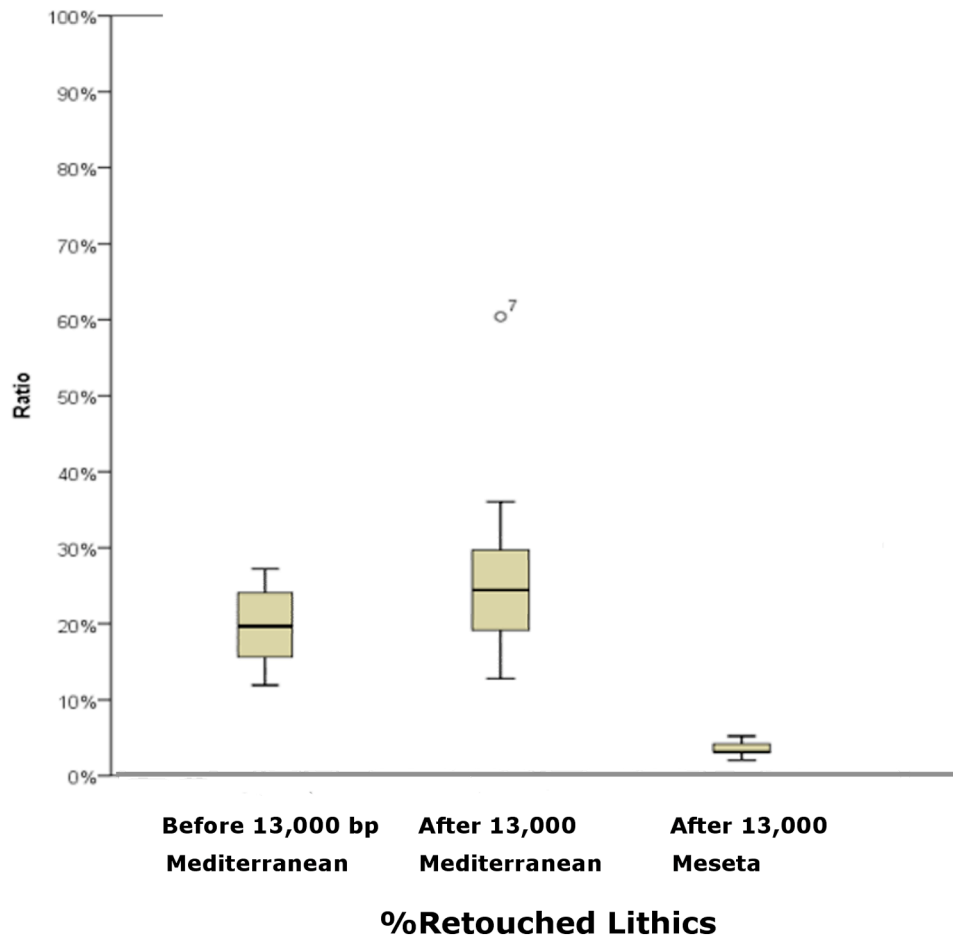


Figure 26. Ratio of retouched lithic pieces to unretouched pieces within assemblages on the Mediterranean littoral and the Meseta.

supplied themselves with “specific resources through specially organized task groups logical groups.” Magdalenian hunter-gatherers appear to have targeted the relatively high meat and fat potential available on the Meseta at a high rate of turnover. They accessed the Meseta for specific resources, but they did not move to the Meseta. The consistent retouch lithic data from the Mediterranean littoral before and after 13,000 bp viewed in context with the low percentage of retouched lithics on the Meseta suggests that the necessary lithic tool kits (Kuhn 1994) were restored prior to Meseta hunting sorties.

Few retouched lithics had time to accumulate. Most discarded lithics on the Meseta would have been unretouched expedient flakes. This is consistent with Davidson's observations for the survey area around El Niño near Albacete (Davidson 1986), where lithic scatters of expedient flakes on local quartzite raw material made it difficult for archaeologists to associate those groups with Upper Paleolithic groups who created the assemblages in Mediterranean Spain. The expedient flake scatters appeared "archaic" and thus much older than the Late Upper Paleolithic lithic assemblages on the Mediterranean littoral.

Attribution to earlier periods based on the expediency of unretouched lithics is not an isolated occurrence on the Meseta. In another case, the expedient lithic assemblage at El Palacio near Valladolid was originally attributed to the Châtelperronian, however now researchers place the same assemblage within the Late Glacial (Delibes de Castro and Díez Martín 2006: 19).

Mobility Trends and Routes

To determine where hunter-gatherer groups from the littoral may be going and how they may have gone there, this study analyzed Least-Cost-Paths generated using Geographic Information System calculations from a digital elevation model of Mediterranean Spain and the Meseta. Sites are defined as residential caves and rock shelters, rock art locations, and raw material sources. A Least-Cost-Path is the most efficient route between two points measured in time and distance. Given the elevation changes in the mountain valleys between

the Mediterranean littoral and the edge of the interior Meseta, time is a more valid measure than distance.

- Least Cost Path (LCP) analysis of routes generated by GIS using digital elevation models (DEMs) of the study area and the coordinates of known archaeological sites.
- Sites are defined as residential caves and rock shelters, rock art locations, and raw material sources.
- LCP is the most efficient route between two points on a landscape as measured by time and distance.
- Time a better LCP measure than distance on the topography of an irregular landscape with marked changes in elevation.

The GRASS GIS program reports Least Cost Path time in seconds to allow for as much nuance as possible. The seconds have been converted to hours for this research, and a construct called Travel Days or Working Days has been created. Since daylight is necessary for most travel and tasks in the Upper Paleolithic, a Travel Day is a unit based on available daylight. The annual mean for daylight hours is 12-hours, from which two hours has been subtracted to get a group moving in the morning. Another two hours is subtracted from a Travel Day to allow time to find and make camp in the afternoon. And an hour is subtracted for a one hour mid-day break.

- Travel day = 7 hours
- Mean annual number of daylight hours (12 hours)

- Less two (2) hours start up in the morning
- Less one (1) hour mid-day break
- Less two (2) hours camp preparation in the evening

Least Cost Path Selection Criteria

- LCP measured by travel days should end at a point (resource patch) with greater foraging potential than the point of origin.
- LCP must be associated with material correlates of a human presence (e.g., artifact scatters, raw material sources, rock art).
- LCP should fall within the distance parameters of Whallon (2006) model for non-utilitarian mobility.

For the Meseta terminus of these Least Cost paths focuses on El Palomar and Molino de Vadico – as well as El Niño a site surveyed and excavated by Iain Davidson in the late 1970s and early 1980s.

The computer generated least cost paths from Cova de les Cendres on the Mediterranean littoral to El Palomar and El Niño on the edge of the Meseta are between the regular travel interval for regional social systems in Whallon's model of social travel and the interval for less frequent travel in maximal band systems (Whallon 1986). Given the added incentive of large herbivores in large herds and the opportunity for aggregation or communal hunting, it becomes even easier to view these distances as fitting within the regular travel intervals Whallon proposes are necessary to keep social relationships and alliances active. Although as noted above, the relative frequency of retouched lithic pieces is low on the Meseta, indicating a comparably low discard and accumulation rate,



Figure 27. Least Cost Paths from Cova de les Cendres to the southeastern edge of the Meseta at El Niño and El Palomar. Cost/distance measured in travel days.

Davidson (1986) noted a high overall frequency of expedient lithic scatters noted in the surveys conducted around the El Niño area. As noted previously, the El Niño area is located between the upper drainages of the Guadiana River, which flows south into the Atlantic Ocean and the Júcar River, which flows east into the Mediterranean Sea (Figure 15). This combination of an apparently high frequency of short-term stays and its location at the nexus of two major river

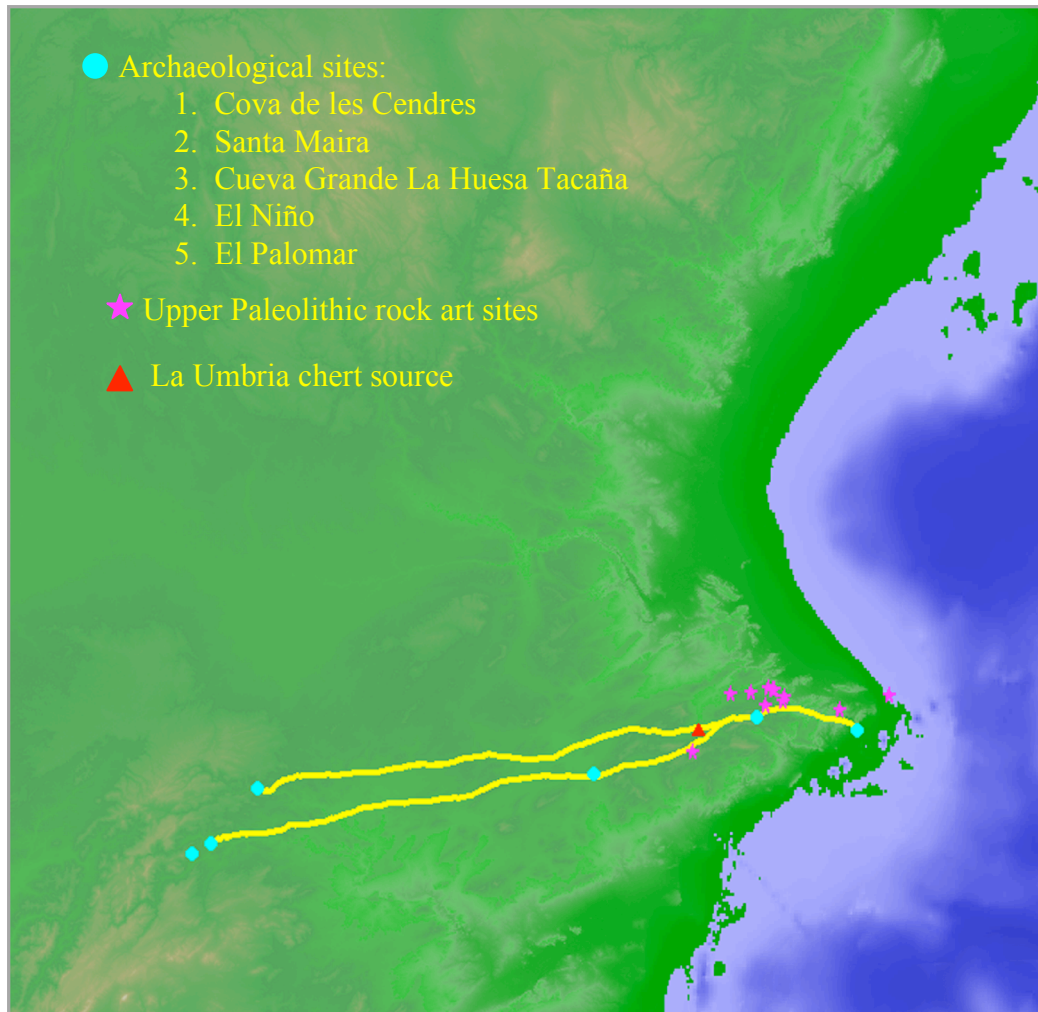


Figure 28. Alternative routes for Least Cost Paths from Cova de les Cendres to the southeastern edge of the Meseta at El Niño and El Palomar. Cost/distance measured in travel days.

drainages that could have formed natural corridors for travel from two different coastal areas is used here to postulate the El Niño area as a possible aggregation site (Conkey 1980) for hunter-gathers during the Pleistocene-Holocene transition.

Forager Mobility

The GIS-generated Least Cost Paths (Figure 27) place the routes to the Meseta farther south than might be expected from the region's archaeological



Figure 29. Magdalenian backed bladelets from Cova de les Cendres. Honey colored bladelets with white flecks visually match chert found at the La Umbria source near Alcoi. (Villaverde et al. 2012)

data. Groups at Cova de les Cendres exploited a chert source in La Marina Alta near Alcoi (Villaverde et al. 1999: 24) (Figure 29), now known as La Umbria (Faus 2008) (Figure 30), that has cobbles of distinctively colored, high quality raw material. La Umbria chert has also been visually identified at Cueva Grande la Huesa Tacaña, a site with a Magdalenian component on the eastern transition



Figure 30. Chert cobble from La Umbria source near Alcoi.

edge of the Meseta. Rock art in the Mediterranean region on the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage List has been associated with the Upper Paleolithic either through art association or artifact association (UNESCO 2011). In addition, the site of Santa Maira in La Marina Alta has a Magdalenian basal layer and, therefore, must be considered when ascertaining mobility routes (Aura 2001; Aura et al. 2005). If alternative routes are established for Least Cost Paths incorporating these archaeological data (Figure 28) a new analysis (Table 5) indicates that the paths still fall within the parameters for social travel in Whallon's model (Whallon 2006) (Figure 31).

Cova de les Cendres	to	El Niño					
225.9 kilometers		45.7 hours		6.5 travel days			
Cova de les Cendres	to	El Palomar					
240.8 kilometers		49.0 hours		7.0 travel days			
Cova de les Cendres	to	Molino del Vadico					
249.2 kilometers		51.1 hours		7.3 travel days			
Cova de les Cendres	via Santa Maira	to El Niño		Total hours	Travel days		
39.4 kilometers	8.3 hours	182.8 kilometers	37.4 hours	45.7 hours	6.5 travel days		
Cova de les Cendres	via Santa Maira	to El Palomar					
39.4 kilometers	8.3 hours	202.7 kilometers	41.5 hours	49.8 hours	7.1 travel days		
Cova de les Cendres	via Santa Maira	to Molino del Vadico					
39.4 kilometers	8.3 hours	211.1 kilometers	42.9 hours	51.2 hours	7.3 travel days		
Cova de les Cendres	via Santa Maira	via La Umbria	via La Sarga	via Huesa Tacaña	to El Niño	Total hours	Travel days
	8.3 hours	5.0 hours	2.0 hours	7.1 hours	25.0 hours	47.4 hours	6.8 travel days
Cova de les Cendres	via Santa Maira	via La Umbria	via La Sarga	via Huesa Tacaña	to El Palomar		
	8.3 hours	5.0 hours	2.0 hours	7.1 hours	28.7 hours	51.1 hours	7.3 travel days
Cova de les Cendres	via Santa Maira	via La Umbria	via La Sarga	via Huesa Tacaña	to Molino del Vadico		
	8.3 hours	5.0 hours	2.0 hours	7.1 hours	30.9 hours	53.1 hours	7.6 travel days

Table 6. Distance and travel day costs for alternative routes from Cova de les Cendres to the southeastern edge of the Meseta.

Forager mobility in this study is employed as a proxy for social relationships and information flow across the Pleistocene-Holocene transition. Forager mobility is not solely a consequence of optimizing subsistence strategies in space and time. It incorporates optimizing strategies as well as establishes and maintains networks of information flow among widely scattered groups that function as a ‘social safety net’ in contexts of local resource scarcity. These relationships must be active and reliable – which requires travel by contact and the flow of information on a consistent basis.

Information flow can be expressed quantitatively at three spatial scales derived empirically from ethnographic data.

Minimal Bands: Modal Spatial Organization

1. 25-30 individuals, all age.
2. Extent of spatial territory ca. 2,500 km²

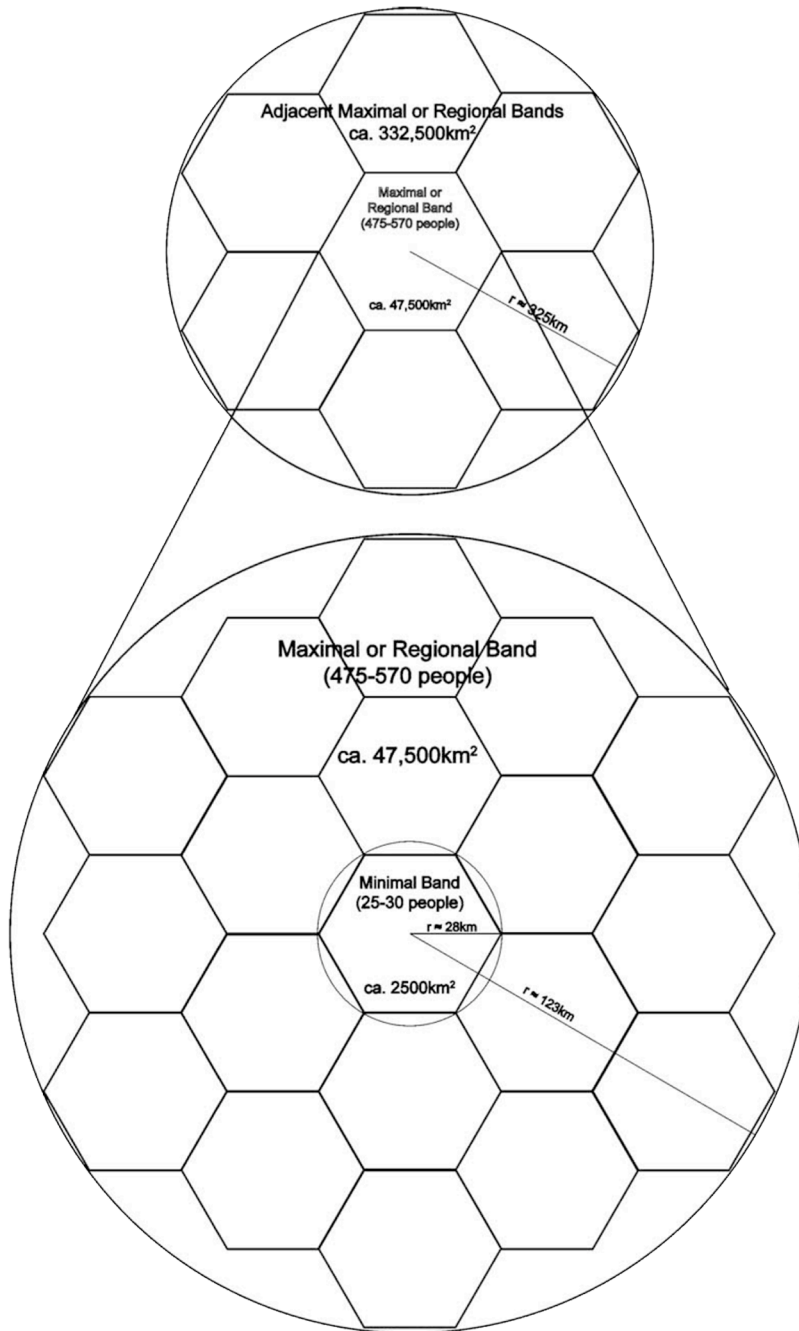


Figure 31. Whallon Model of non-utilitarian travel.
Based on band spatial organization.
(Whallon 2006: 267, Figure 4)

3. Travel radius ca. 25-28 km
4. Corresponds to home subsistence range
5. Residential (circulating) or logistic (radiating) mobility
6. High resolution information flow extends to adjacent minimal bands
7. Resolution decreases with distance

Regional Bands: Modal Spatial Organization

1. 475-570 individuals, all ages
2. Extent of spatial territory ca. 47,500 km²
3. Travel radius circa 125 km
4. Adjoining minimal band territories
5. Sustained by travel to maintain stable relationships
(e.g., marriage, alliance networks; communal hunting)
6. Intermediate resolution information flow extends to adjacent
regional bands
7. Resolution decreases with distance

Maximal Bands: Modal Spatial Organization

1. $\geq 3,325$ individuals (7 or more regional bands)
2. Extent of spatial territory ca. 332,500 km²
3. Travel radius circa 325 km
4. Characterized by exchange networks and down-the-line trade
5. Low resolution information flow can extend down to the level of
minimum bands
6. Resolution decreases with distance

Social Communication

Looking from La Peña de Estebanvela north to the Pyrenees (Cacho et al. 2012), there is evidence of contacts in the commonality of the most characteristic motif in the portable art found at the rock-shelter, which is also found at a litany of French sites: Gourdan (Haute Garonne), Espelugues (Haute Pyrénées, Dufaure (Landes) and Rhodes (Ariège). From Rhodes at Ariège, the contacts extend even further from the Meseta to Pages (Lot) – about 80 kilometers from Les Eyzies-de-Tayac-Sireuil and the heart of the Franco-Cantabrian refugium in the Périgord-Dordogne region (Cacho et al. 2012). The similarity in portable art strongly suggests contact with sites as distant as Rochedane on the Swiss border. This suggests the existence of long-distance contacts with these Magdalenian groups south of the Duero Valley (on the northwest Meseta between Madrid and Burgos). Working from the Meseta south to the Mediterranean, Cacho and Perez (1997: 272) look at similarities of art and see the connecting river valleys as “natural passages to the coast” (“*pasos naturales hacia la costa*”) – particularly in the Valencia area that forms the northern border of La Marina Alta. From the region where Switzerland, France, and Germany now meet through the open interior plateau of Spain to La Marina Alta, where the southeastern Mediterranean coast of Spain at Capo de la Nao reaches closest to north Africa:

“Certainly, it would seem to reflect a symbolism common to Magdalenian groups in Western Europe at the end of the Pleistocene, despite major differences in regional ecology.” (Cacho et al. 2012)

These nodes of communication that linked family-based relational bands to socially bounded geographic territories to aggregated fusions of extended communities that could be sustained only temporarily during the Pleistocene-Holocene transition were the lines along which traveled the first stories we told to faces we may not have recognized in contexts that were not entirely of our own making or choosing. Eventually, as the stories we told each other became more established and formatted, they would serve to both connect and divide us further. But most important of all, these terminal Pleistocene and early Holocene lines of communication were the social corridors for information exchange.

The lines of communication and information exchange established the means by which social groups during the Pleistocene-Holocene transition initiated and maintained risk mitigating alliances (Whallon 2006). Whallon used data inputs from the Magdalenian to create his models, but similar parameters have been noted for social mobility in the Paleo-Indian period of North America (MacDonald 1998, 1999).

As sea level rose in the Mediterranean after the Last Glacial Maximum, hunter-gatherers in the littoral area (the most densely populated region of Eastern Spain as determined by the number of archaeological sites) reached a tipping point at about 13,000 bp, after which they turned to face west, toward the Meseta, when optimal foraging decisions dictated they target the largest available meat yield prey with highest available fat content.

CHAPTER 7

CONCLUSIONS

1. We divide the Upper Paleolithic into study areas by necessity. The reality occupied by foragers in Mediterranean Spain (for example) across the Pleistocene-Holocene transition was wider and more inclusive than site based areas of study.
2. Human adaptation to the resulting environmental transformation in Mediterranean Spain was an ongoing process and not a situational event. It was a continuum across space and time not a segment of space or time.
3. Humankind has always lived in an information age. Information flow was (and is) an essential component of social relationships, including exchange networks. As previously noted by Childe (1949, 1956), and observed in another context by Luhmann (1989a, 1989b), groups who could not socially communicate about the environment and changing environmental conditions, probably did not live long enough to accumulate an archaeological record.

The transition from Pleistocene to Holocene triggered environmental processes comparable to those the United Nations Framework Convention on Climate Change (UNFCCC 2005, 2004) included in the Kyoto Protocol (UNFCCC 1999, 1998). Outcomes of the transition at about 11,000 years before present (Broecker 1966) – glacial retreats, sea level changes of more than 100 meters, shifts in weather and rainfall patterns, and reconfigurations of floral and faunal ecologies (Straus 1996a, 1996b) – contrast sharply with subsequent climate oscillations (IPCC 2001) that predominated until Svante Arrhenius (1896) recognized the signs of anthropogenic climate change. Climate oscillations are cyclical. After oscillating the system eventually returns to a state similar to the one in which it started. With the addition of anthropogenic triggers to the natural system (Karl and Trenberth 2003; Williams et al. 2007), we now appear to be facing a climate transformation, when climate passes a threshold and assumes distinctly new characteristics (Redman and Kinzig 2003). This is one of the challenges in understanding climate change and its effects. Transitory oscillations come back to a familiar coherence. Climate transformation results in novel relationships (Williams et al. 2007). Within the transformation process, nonlinear contingent events internally calibrate the trajectory. The cumulative effects of contingent events are such that evolutionary theorist Stephen Jay Gould proposed if the process of biological evolution was rewound some 500 million years to the Cambrian, and the contingent interplay of selective forces played-out again, humankind would not evolve a second time (Gould 1989: 51). Contingency also creates challenges at archaeological time-depths (Barton et al 1999). As a result,

past climates cannot be used as snapshots illustrating specific climate outcomes in the future (Crowley 1990).

However, the structure of the process within which contingent events occur is an important conceptual framework. For example, the solar system is not a snapshot of any single atom within it. But using the solar system as a conceptual framework, Niels Bohr proposed his atomic model of a compact central nucleus surrounded by orbital electrons (Wilson 1964). Bohr's original atomic model (Bohr 1913) has been succeeded by more sophisticated theories of quantum mechanics (Wilson 1964) that have incorporated contingency. Bohr applying the structural process governing the solar system as conceptual framework for understanding atomic systems made these new insights possible. It is a pattern of theoretical descent with modification that is familiar in archaeology. Bohr's work earned the 1922 Nobel Prize in Physics (Nobel Foundation 2007).

There is strong support for using past climate transformation as a conceptual framework to understand the process of adaptation to modern climate change. Evidence indicates that climate transformations during the past 1.6 million years of the Quaternary have occurred as quick leaps and not incremental changes (Adams et al 1999). The Pleistocene-Holocene transition and modern anthropogenically-driven climate transformation display close correspondence in this important functional aspect (Karl and Trenberth 2003, Gibelin and Deque 2003, Giorgi et al. 2001, Greiner 2004, van der Leeuw 1998). In dealing with the resilience of systems to climate transformations, ecologists note the lack of

current analogs with which to validate predictive models (Martínez-Meyer *et al* 2004). They have proposed using paleoecological and paleoclimatic data to evaluate the coherence of ecological models to environmental conditions outside the limits of modern values. Detailed paleoenvironmental data indicate the past is the key to understanding the present – current systems are still strongly influenced by the Pleistocene Ice Age (Kauffman 1987).

Climate is a primary constraint on species distribution and ecosystem function (Williams et al. 2007). By extension, it is a primary factor in human subsistence adaptation. Ecological systems exhibit nonlinear responses to climate, placing critical importance on a conceptual framework for ecological responses to novel climates (Clark et al. 2001). Whereas “forecasts are impeded by the difficulty of predicting ecological responses to environmental conditions outside the range of current experience” (Williams et al. 2007), our understanding of elements such as species range shifts, extinction risks, and biome changes is “reinforced by observed ecological responses to the last deglaciation, which were characterized by large changes in species ranges, and, in places where past climates apparently lacked modern analogs, the development of species associations and biomes with no modern counterpart” (Williams et al. 2007),

The Pleistocene-Holocene transition (the last deglaciation) being a viable conceptual framework for ecological adaptation writ large, the issue then becomes the specifics of human adaptation within that framework – whether the structural elements of this ecological solar system map onto elements of what is essentially the atom of human adaptation such that the relationships remain viable. This

degree of isomorphic mapping between conceptual structures is the key to ampliative reasoning – reasoning that compares two situations to draw conclusions about previously unknown properties of one – in the philosophy of science (Weitzenfeld 1984). In this context, the key is defining human adaptation as subsistence adaptation, specifically adaptation by the world's small stakeholders, who are on the vanguard of risk from an anthropogenically-driven climate transformation (IPCC 2007a). The most vulnerable societies are those whose subsistence economies are closely linked with climate-sensitive resources (IPCC 2007a).

The degree of isomorphic mapping between human subsistence adaptations in the 21st century and the Pleistocene-Holocene transition is higher than may be evident initially. The Intergovernmental Panel on Climate Change notes that small stakeholders “practice hunting-gathering of wild resources to fulfil energy, clothing and health needs, as well as for direct food requirements” (Easterling et al. 2007). Modern climate change literature focuses on human vulnerability, adaptation and resilience with migration (including remittances as a form of migration) and local intensification as the primary human responses (e.g. Adger et al. 2002, 2001; McLeman and Smit 2006; Smith et al. 2000; Yohe and Tol 2002). Redding's (1988) model of prehistoric subsistence, a generalization of Flannery's (1969) argument for the origins and ecological effects of early domestication, identifies the same factors as Pleistocene-Holocene hunter-gatherer responses to vulnerability.

Assuming the efficacy of defining successful subsistence adaptation as having access to sufficient resources, hunter-gatherer economies in Mediterranean Spain at the Pleistocene-Holocene transition balanced a set of variables analogous to those of local subsistence economies in climate-sensitive developing nations today. Sweeping changes in demography between the onset of the Holocene and now alter what is sufficient, as differences in technology modify the degree and pathways of access, but neither alters the internal cohesion of the definition. Understanding the elements of successful adaptation to climate change in a local context is a requisite to inclusive research on the modern climate transformation in which we are playing an active role. The Pleistocene-Holocene transition is the only available record covering the full trajectory of human response to a climate transformation (Eriksen and Straus 1998, Straus 2000, Straus et al 1996a, 1996b).

The climate impacts projected to result from increasing greenhouse-gas concentrations already exist as a major concern in the world (Pielke et al. 2007). New models show late Pleistocene climate change probably occurred as rapidly as modern, anthropogenic climate change (e.g., Barton 2004, Adams et al. 1999) – the difference being the triggers that push the system past its thresholds (van der Leeuw and Redman 2002, Redman and Kinzig 2003). The eighth session of the United Nations Framework Convention on Climate Change introduced the ‘Delhi Declaration’ calling for greater attention to human adaptation in international policy (Pielke et al. 2007). Knowing the dynamics of long-term local adaptations to the Pleistocene-Holocene transition is essential to creating strategies for the subsistence economies most vulnerable to the climate change of our own doing.

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